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2) PALMER, E.

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TO

His Royal Highness Prince Albert.

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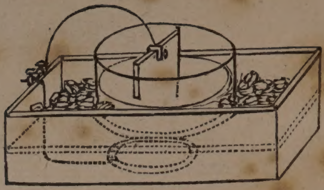

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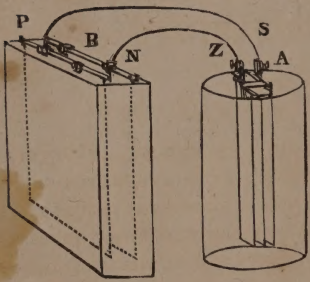

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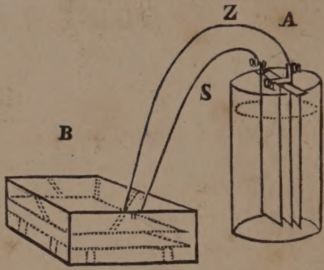

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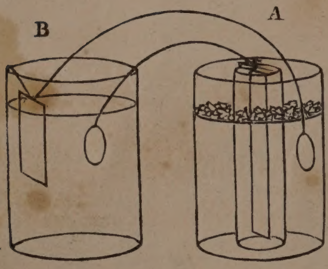

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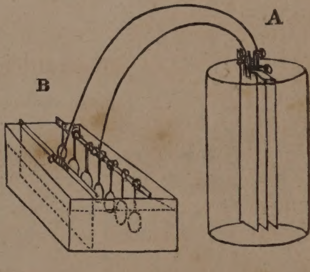

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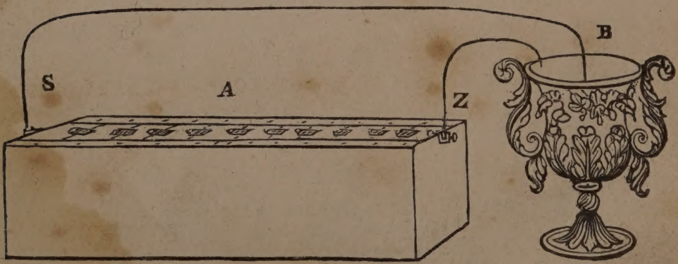

ELEMENTS

OF

ELECTRO-METALLURGY,

OR

THE ART OF WORKING IN METALS BY THE GALVANIC FLUID;

CONTAINING

THE LAWS REGULATING THE REDUCTION OF THE METALS, THE STATES IN WHICH THE DEPOSIT MAY TAKE PLACE, THE APPARATUS TO BE EMPLOYED, AND THE APPLICATION OF ELECTRO-METALLURGY TO MANUFACTURES; WITH MINUTE DESCRIPTIONS OF THE PROCESSES FOR ELECTRO-GILDING, PLATING, COPPERING, &c.; THE METHOD OF ETCHING BY GALVANISM, THE ART OF WORKING IN GOLD, SILVER, PLATINUM AND COPPER, WITH FULL DIRECTIONS FOR CONDUCTING THE ELECTROTYPE.

(Illustrated with Wood Cuts.)

By ALFRED SMEE,

Surgeon to the Bank of England, Surgeon to the Provident Clerks' Mutual Benefit Association,
&c. &c.

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1841.

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TO HIS ROYAL HIGHNESS

THE PRINCE ALBERT, K.G.

Sir,

The honour of being allowed to dedicate this volume to your Royal Highness, must be attributed rather to the earnest desire of your Royal Highness to promote the arts and sciences, than to the merits of the work itself. As I have endeavoured to aid the manufactures of Great Britain, by giving these discoveries to the public, I trust this book will receive your Royal Highness' gracious approbation.

I remain,

With the greatest respect,

Sir,

Your Royal Highness most dutiful

and most obedient Servant,

ALFRED SMEE.

DESCRIPTION OF THE WOOD-CUTS.

(Fig. 1.) This is the most simple form of single cell apparatus. It consists of an outer vessel which contains a saturated solution of sulphate of copper, and some undissolved crystals of the salt suspended at the upper part of the solution; in this the medal to be coppered is placed. The inner vessel here represented, is made of porous earthenware, and contains the dilute acid, and the rod of zinc, which is seen to be connected by a wire to the medal. The inner vessel may be changed for a glass tube drawn to a capillary point, or any other porous apparatus, suitable to different cases. (108,) (110,) (114.)

(Fig. 2.) This is another form of simple apparatus. It consists of a square box containing the sulphate of copper, and an inner one containing the inner glass vessel, the mouth of which is closed by bladder. This contains the acid and zinc. To those who prefer the single cell apparatus, this form is the best, for every part of the apparatus is well suited to perform its respective function.

(Fig. 3.) The battery that is here represented (A) consists of a piece of platanized silver in the centre, to which a binding screw is attached to allow the wire (S) to be connected with the positive pole of the decomposition apparatus, which consists of a sheet of copper, to be dissolved during the action. The zinc is in two pieces, which are connected together by a binding screw to allow connection by another wire (z) with the negative pole (n), or in other words, to the plate to be manufactured. The precipitating trough (B) is a flat parallelopiped shaped vessel, containing at the top two pieces of metal, which afford conveniences for the attachment of the wires and poles. The single battery apparatus is applicable for silver, and all other metals having a greater affinity for oxygen. 117, 120.

(Fig. 4.) This is a similar apparatus to the last described, with the exception that the precipitating trough is horizontal. This form of apparatus should be always adopted where the deposition is required to take place with great rapidity. The plate or object to be copied is placed at the bottom of the vessel, and is connected to the zinc of the battery by the wire, whilst the piece of copper is put from half an inch to an inch above it, and is connected to the zinc of the battery.

(Fig. 5.) Mason's arrangement, by which one equivalent of zinc reduces two equivalents of copper. (A) is nothing but a simple cell, similar in every respect to fig. 1, except that the zinc instead of being at once connected to the medal in the sulphate of copper, is joined by means of a wire, to a medal, in a solution of sulphate of copper in the precipitating trough (B). The medal in the first vessel or battery vessel (A) is connected to a piece of sheet copper in the precipitating trough (B) which forms a positive pole to the second cell, and thereby completing the series. The electric current would thus pass from the zinc in (A) to the medal in (B), where metal would be reduced from the solution, an equal weight of the plate of copper would be dissolved, and the current would then pass back to the medal in the first vessel (A); there reduce the copper from its sulphate, and thus complete the circuit. 121.

(Fig. 6.) This wood-cut is intended to show the mode of arranging a number of medals; the battery (A) is the same as that described for (fig. 3 and 4). The precipitating trough (B) is the same as (fig. 1). The medals are seen to be connected to the bindingscrew of the zinc of the battery, whilst the piece of copper to be dissolved is joined to the platanized silver. This form of apparatus is suitable for making a number of medals at once of any size. A bar is fixed across the top, which is connected with the zinc of the battery; on this the wire of each medal is hung, and in this way each may be removed separately for examination.

(Fig. 7). The compound battery apparatus is here given. The battery (A) is an ordinary many-celled porcelain trough, containing a compound platanized silver battery; the number of cells required, will be from three to twelve cells. A wire joined to the silver of the battery is connected with a fine platinum wire, and the operator regulates the quantity of electricity by the distance this is immersed in the fluid; (Z) is a wire connected to the zinc of the battery, to be connected to the negative plate, 115, 116. The precipitating trough (B) in this instance, is a vessel to be gilt, but this apparatus is absolutely essential to all metals which require a platinum positive pole, and therefore it must be used for the reduction of gold, platinum, palladium, nickel, &c.

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ON GALVANIC ETCHING,

PREFACE.

Last summer I was requested to write an epitome of the electrotype, a task which I was most unwilling to undertake. Upon being much pressed, however, I at length consented, solely on account of my conviction of the necessity which then existed of investigating the subject experimentally. I accordingly entered upon my task, and as soon as I had satisfactorily developed the laws regulating the precipitation of the metals, I found that the isolated fact of the reduction of copper, was but one of an extensive series of facts, all of which were regulated by the same laws; and instead, therefore, of having before me, simply the electrotype, as the boundary of my labours, I found myself embarked upon a new and comprehensive science. The laws above mentioned led to the various new applications which are interspersed throughout this volume. Many of them I had originally thought of patenting, but upon second consideration I determined to throw the laws and principles open for the benefit of the arts and manufactures of our great country. The application of these laws and principles are fully detailed, and if they tend to further that great object, it will indeed be an ample recompense for all my labours.

Every thing that is new in this treatise is given freely to the manufacturers of this country, and I may mention that every thing which I have hitherto invented or improved upon, has also been in a like manner thrown open.

The scientific man in England has neither to expect remuneration from an Emperor, as the Russians have, nor from the Chamber of Deputies as the French have, nor can he look forward to those honors and distinctions which are conferred upon illustrious Germans. For what then does he labour? It is solely for the sake of science, and he is contented and satisfied with developing new scientific truths, or promoting the prosperity of our national manufactures.

The plan upon which this work is arranged, is that which I considered would prove most serviceable to the practical man. A brief epitome of galvanism is here subjoined, because the science of electro-metallurgy is radically founded upon that principle, and therefore absolutely dependent upon a thorough knowledge of it, for its successful practice. In fact, it would be in vain for any one to attempt to practise it, without being thoroughly conversant with the properties of galvanic batteries. The various laws and their applications are not in that order which would have best suited an original paper; as in this work, the laws and the modes of carrying them out, have been first given, and the experiments and facts from which these laws have been deduced, have been subsequently detailed. The inductive reasoning would of course have required an opposite arrangement, but although the last is best adapted for

an original paper, the first appears to be preferable for a treatise designed for the use of the operator. It was originally intended to have illustrated the part of this work devoted to the electrotype in all its branches, but it was found that the expense attending such a procedure would have necessarily limited the benefit which I trust the public generally will derive from the work. It has therefore been proposed by Mr. Palmer, who executes the electrotype engravings, to publish a separate work, as an accompaniment to this, and illustrating the application of the electrotype to every species of engraving.

This arrangement I instantly complied with, because it allowed this volume to be published earlier, and did not prevent those desirous, from possessing the illustrations; and what is of most importance, allowed the whole of the illustrations to be rendered quite perfect before they were submitted to the public.

In these elements I have had frequent occasion to mention works, and enter into arts far removed from my profession, and although I have endeavoured to obtain the best information on these points, yet errors are necessarily liable to occur. For these, the pardon of the reader is entreated, and it is hoped he will recollect that this work is designed expressly to teach electro-metallurgy, and that therefore all matter, not essentially relating to this science is foreign to it. The whole of this treatise may be deemed by many to be quite irrelevant to the business of a surgeon. I cannot, however, but feel, that the most intimate knowledge of natural philosophy and chemistry, should always be combined

with anatomical knowledge by him who ventures to prescribe for the delicate fabric of the human body.

In laying this work before the public, I am well aware that it is likely to contain faults and imperfections; the reception, however, which my other original papers have met with, both at home and abroad, has been as favourable as I could have desired, perhaps more so than they deserved. This encourages me to venture again before the public, trusting that the new matter which the present volume contains, will in some measure atone for any errors which may here exist. I must not forget to mention, that these errors have been materially lessened through the kindness of my friend, Mr. John Beadnell, who was so good as to revise the whole of the proof sheets. To my brother-in-law, Mr. Hutchison, I am also obliged for the analytical index.

The principles which are laid down, and the full directions which are given in this work, will be amply sufficient to regulate the proceedings of the operator; but he must recollect that electro-metallurgy is not only a science depending upon ascertained and fixed laws, but also an art, depending for its success upon skill and practice; still, if he follow with patience the processes which are here detailed, I feel assured that he will meet with complete success.

Bank of England,
Nov. 2nd, 1840.

HISTORY

OF

ELECTRO-METALLURGY.

To trace the history of the art of working in metals by the galvanic fluid, we have not to extend our enquiry into remote periods, for truly it may be said that this art belongs to our own time, and is a characteristic of the present age. Whilst however, we pursue our investigations into the history of this subject, we find that it has had by no means a sudden origin, for by degrees, at different periods, various persons have worked out one fact after another, till the comprehensive science has been developed, of which this volume is but a brief epitome. The art may be said to have had its origin in the discovery of the constant battery by Professor Daniell, for there the copper was continually reduced upon the negative plate. In his first experiment, this distinguished author observed, on removing a piece of the reduced copper from a platina electrode, that scratches on the latter were copied with accuracy on the copper. In this experiment we have the electrotype; but the author, in this paper, had devoted all his attention, and centered all his energies to the construction of the battery itself, and this valuable fact attracted but little of his notice.

It was not a long time after the discovery of this battery, that Mr. De la Rue experimented on its properties. In a paper printed in the Philosophical Magazine for 1836, after describing a peculiar form of battery which he adopts, the following remarkable passage is found: "The copper plate is also covered with a coating of metallic copper, which is continually being deposited; and so perfect is the sheet of copper thus formed, that being stripped off, it has the counterpart of every scratch of the plate on which it is deposited." This paper appears to have attracted very little attention; and what appears still more singular, the autbor, although well qualified, from his scientific attainments, to have applied these facts, never thought of any practical benefit to which this experiment might lead.

In this state the subject remained till October, 1838, when Professor Jacobi first announced that he could employ the reduction of copper, by galvanic agency, for the purposes of the arts. His process was called galvano plastic. Immediately upon his discovery being announced in this country in 1839, Mr. Spencer stated that he had executed some medals in copper, to which the public afterwards gave the name of electrotypes or voltatypes.

Now what is the precise value of the discovery of these productions over the facts already described?—for we have seen that the reduction of the copper, as a perfect plate, taking the exact form of the negative metal on which it was deposited, had been already noticed. Why, it is simply the idea of the application of these facts; but that idea has been everything. The only apparatus which Mr. Spencer employed, was in fact, a simple Daniell's battery. He employed various metals for the reception of the precipitated metal, which however, was nothing new; but he does not seem to have succeeded with any non-conducting substances. He executed medals, and perhaps duplicate copper plates; but he does not give any details, as to the different methods for the reduction of the copper in different states, neither did he succeed with the

reduction of any other metal. However, to Mr. Spencer the British public are principally indebted for the idea of the electrotype; and perhaps the idea, as far as relates to its application in Great Britain, originated entirely with himself.

Mr. Spencer's first paper was printed in the journal of the Polytechnic Institution of Liverpool, in 1839; but the author complains, that by mismanagement it was prevented from being read at the British Association. Any discouragement of science in the present time is greatly to be lamented, and the more especially when we see that the Germans are already taking the lead, not only in chemistry, but also in physiology. Every well-wisher of science must hope that an over anxiety to prevent the publication of what is old, will not cause the referees of our learned societies to omit what is new. However, we are not so much behindhand, but that a little zeal on the part of those who have an established reputation for scientific acquirements, joined to the effect which encouragement would have on the junior members of the country, will enable the British to keep the foremost rank in science among the European nations. There are many now working zealously and ardently for the sake of obtaining truth, struggling against the most disheartening opposition: let that opposition be changed for assistance, and great indeed will be the results.

Perhaps in this place I may call the attention of scientific men to the fact, that persons are actually employed by great continental powers to find out every thing new that is discovered in this country, which, in a very few hours can be conveyed to any part of Europe. This hint is thrown out, not to deter Englishmen from generously giving their discoveries to all countries, but to cause them to be cautious not to mention their processes till they have appeared in some British publication, and thus vindicated the scientific character of our own country. This is the more necessary, as the English receive only the pleasure which the consciousness of being useful must afford, whilst the foreigner receives pecuniary emolument,

which singularly increases his desire of being acquainted with the inventions of other countries.

I may further notice, in order to confirm what I have already stated, that the galvano-plastics of Jacobi, and the electrotype of Spencer, is not a science which is the result of inductive reasoning and laborious research, like Professor Wheatstone's electro-telegraph, but merely an application of a fact formerly known to Daniell, recorded particularly by De la Rue, and observed by hundreds of others, that both Spencer and Jacobi could work only in copper, and in no other metal; whilst, had they prosecuted their subject as a science, they would have seen that the same laws regulate the reduction of all the metals.

The next discovery, which is fully equal in value to the idea of the electrotype itself, was made by Mr. Murray. He found out that non-conducting substances might have metallic copper thrown down upon them, by previously applying black lead. His process is extremely simple, and absolutely perfect. The first application of this invention was made in January, 1840; but it is to be lamented that he did not further extend its application and publish his researches, for his method was communicated orally, in the conversaziones of the Royal Institution, and not by any paper. I lay particular stress upon the value and perfection of plumbago, because some have denied its applicability; and the reader will find, in many parts of the work, that I have extended the use of this substance, to the benefit of the public, and to the fame of the inventor. I have made very extensive enquiries, in order to ascertain who really first used plumbago for this purpose, and I have the testimony of several authorities that it was Mr. Murray, whose claim therefore to this invention is rendered quite indisputable.

Other authors, as Mr. Solly and Mr. Spencer, subsequently gave processes for obtaining a metallic coating; but these are far inferior to that of Mr. Murray, besides being more troublesome and expensive.

Up to April, 1840, the single-cell apparatus was invariably used, but then Mr. Mason very ingeniously devised another mode by which the reduction might be effected. He used the single-cell apparatus as a Daniell's battery, which he connected with another cell, to reduce another metal. In the second cell he used a copper positive electrode, which was dissolved during the action. By this means he made two medals by one pound of zinc, or in other words, obtained two equivalents of copper for one of zinc.

However, up to that time, no laws had been determined for the reduction of the metals in different cases, notwithstanding a short paper which I sent to the philosophical magazine, accompanied by an engraving multiplied by my galvanic battery. This was the first electrotype plate that ever had one thousand copies printed from it.

The laws regulating the reduction of all metals in different states are given in this work, as the result of my own discoveries. By these we can throw down gold, silver, platinum, palladium, copper, and many other metals in three states, namely, as a black powder, as a crystalline deposit, or as a flexible plate. These laws appear to me at once to raise the isolated facts known as the electrotype into a science, and to add electro-metallurgy to the noble arts of this country.

The number of experiments, I may even say the thousands, that have been tried to elucidate these laws (for this book is not a detail of experiments, but rather a digest of them) could never have been executed had I not first discovered my galvanic battery; for its simplicity alone enabled me, without any assistance, to undergo the laborious undertaking. I am fully aware that some may disagree with me as to the superiority of my battery over all others for experimental and manufacturing purposes. I shall not flinch upon this account from stating its advantages, especially as they appear to me likely to contribute to general benefit.

The value of the battery process over all others, is its applicability to all cases; moreover, when we use a single cell of

the battery, the quantity of zinc dissolved to do any amount of work, is the same, or even less, than attends the use of the other apparatus, because the local action in a battery of this construction is less than in the single-cell apparatus; and lastly, the quality of the precipitated metal can be regulated with the utmost nicety; and I have no hesitation in stating, that the battery process is the only one that ever can be employed by the manufacturer with advantage.

The platinized silver battery is peculiarly suitable for the operator, for when it is in action it communicates to him the degree of work that it is doing; in fact, it completely talks to its possessor. If the current is very feeble, a faint whisper is heard; if a little stronger, the battery murmurs; if a moderate current is passing, it hisses; but if a violent one, it roars. At this present moment I have nineteen batteries at work in the same room where I am writing, and they are each telling me the work they are performing. This very instant the fall of a heavy ledger in a neighbouring office has jarred two wires into contact, and the roar of that one battery has immediately informed me of the fact, notwithstanding the action of the eighteen others; I have separated the wires, and the universal singing communicates to me that all are now working satisfactorily. Any local action on the zinc in the same way is immediately notified by its different and peculiar voice, and I have been surprised how quickly the experimentor catches the characteristic peculiarity of each noise, which is learnt more readily than the sound of different bells in a strange house.

With regard to the constancy of this battery, I may be expected to say a few words, for although theoretically it is not absolutely constant, yet practically, for the purposes of the electro-metallurgist, its constancy remains for two or three days, or in other words until the battery is nearly exhausted; and then, to replenish the solution of zinc with a fresh supply of dilute acid will not occupy more than half a minute. In recording my own experience of its practical, though not of

its absolute constancy, I can at the same time conjoin the testimony of some of the most extensive manufacturers in this country. Whilst, upon the practical use of the battery I may state, that the platinum never wears off the silver, and that the platinized silver never undergoes the slightest change, or is affected by the slightest local action.

The perfect modes of gilding and plating, &c., must rest alone upon the authority of this work, for although De la Rive has given a process for gilding, it appears, not only from my own observation, but also from the statements of others, doubtful, whether his mode is really voltaic; and certainly the evolution of hydrogen from the object to be gilt, does not at all agree with the laws regulating the precipitation of the metals which I have detailed; in fact, it is diametrically opposite to them. The process given in this work was discovered in August, before I had seen De la Rive's paper. By my process the gold can be obtained of any thickness, an inch or more, if the operator please. The processes for platinating, palladiating, &c., entirely rest upon the authority of this work, for hitherto the reduction of these metals, in any other state than that of the black powder, has been always considered impossible. The electro-metallurgist will be enabled, by the processes which he will find here fully described, to execute reliefs and intaglios in gold, or in fact, in nearly every other metal; facts altogether new in science. The working of all metals except copper, is also due to the discovery of the laws regulating the precipitation of the metals.

Every author has given directions for making moulds on plaster casts in metal; but it is singular, that by no process hitherto known, can a perfect reverse of plaster be obtained. In investigating the cause of this, I soon discovered that the extreme porosity of the plaster was the block over which they had all stumbled, and the difficulty was overcome by rendering the plaster non-absorbent. In this work, the reader will

find, that the copying of reliefs in plaster, is brought to the utmost possible perfection, and by very simple means.

The extended use of white-wax, bees-wax, rosin, &c., for the electro-metallurgist, I trust will be found acceptable. Their manipulation I have given as the result of my own experience, and therefore, doubtless, those who make a trade of working these substances, will find the account not so full as might have been expected, or wished; yet I believe practice alone is required to make the operator perfect in these arts.

The application of electro-metallurgy to the copying of leaves, fruit, &c., is for the first time described in this work. The new mode of etching here detailed, I confidently trust will be also found a valuable adjunct to the knowledge of the engraver. The principle which regulates the adhesion and non-adhesion of the plates will enable the operator to conduct his operations with certainty, a circumstance of no small importance to the engraver; ignorance on this score having already produced untoward results.

In this history, a sketch only has been given of the leading discoveries; but undoubtedly the person who carries out a new science is also deserving of considerable praise, for frequently he has to incur great expense without any immediate prospect of a return for his capital. Many persons are now entering into the electrotype with great spirit, but none at all equal to the manner in which Mr. Palmer has undertaken it.

The laws which I have given in this work, and the universality of their application, will doubtless influence importantly the attainment of the grand object of using the galvanic fluid commonly among our manufacturers; and having thus, as I believe, raised the isolated facts called the electrotype, into a vast and comprehensive science, a new name is required which may be suitable to its importance, and capable of embracing its application. The term which I have ventured to apply to it, is Electro-Metallurgy, or the Art of Working in Metals by the Galvanic

Fluid, and the value of the new nomenclature is evident, when we consider that it takes in every mode by which it is possible to work the metals, either by dissolving, or precipitating them, by the agency of the voltaic current.

As a surgeon, I feel bound to pass my opinion upon the effect which an extensive application of electro-metallurgy would have on the health of the workman, and in one word I may state, that I believe the mode of working in metals by the galvanic fluid is more wholesome, and would be attended with far less deleterious properties than the methods now practised. The use of the salts of gold, silver, and platinum, is liable to discolour the fingers, but the other salts have no particular effect. However, in passing the above decided opinion, strengthened as it is by watching the effects of the experiments on myself, and also from paying attention to the health of some who have reduced electrotype copper by the hundred weight, I feel but little doubt that if the electro-metallurgist was several times in a day to leave his work with fingers covered with metallic solutions, and take his meals without any ablution, and repeat this for a long time, that the quantity of metal which he would thus draw insensibly into his system, might be attended with inconvenience. Several of the processes here detailed, as those of gilding, &c., are likely most materially to benefit the health of the workman as they supersede the use of pernicious mercurial fumes.

The books which the electro-metallurgist may consult for a more extensive knowledge than is contained in the present treatise, are Daniell's Elements of Chemical Philosophy, and Dr. Bird's Treatise on the same subject. He may farther consult the original papers of Faraday, Daniell, and others, in the Philosophical Transactions of the Royal Society, and he ought by all means, for a description of the metallic salts, to make use of that complete Encyclopedia of Chemistry, by Professor Brande, which has been erroneously named a manual.

It has often been mentioned to me, and considered strange that the societies, whose business it is to superintend and cherish the rising arts and infant sciences, should not contain any single paper on the new science of electro-metallurgy, and that the student is compelled to obtain his knowledge from other sources. For the electrotype, he may possess Spencer's treatise on that subject, although the mode of proceeding detailed by him is very different from those which the laws I have developed, require me to recommend. Jacobi has written a treatise, in German, on Galvano Plastics, De la Rive's paper on gilding, is translated in the Polytechnic Journal, where it can be easily procured, and there are besides various original papers in the Literary Gazette, Athæneum, and Philosophical Magazine, upon the electrotype. The value of these excellent periodicals in making public new discoveries and fostering talent which would otherwise be frequently crushed by the overwhelming weight of interested opinion, is here evident, and to their spirited editors this country is daily owing increase of knowledge, power, and wealth.

BOOK THE FIRST.

ON GALVANISM.

CHAPTER I.

ON GALVANIC BATTERIES.

Electricity; various kinds, 1—8. Voltaic Batteries; circumstances advantageous or disadvantageous to, 5—13. Proximate cause of Galvanism, 14—18. Quantity or intensity, 18—24. Different forms of Batteries, Couronne des Tasses, Wollaston, &c., 24—31. Adhesion of the hydrogen to the negative plate; amalgamation of the positive, 34. Daniell's Battery, 37—44. Grove's Battery, 45—47. Smee's Battery, 48—55. Comparison between the three, 56—58. Conclusion, 58.

(1.) As chemists have arranged an extensive series of effects under the general term of heat, so they have named another series light, and a third, they have called Electricity. Of the first cause of all these, as of that of vitality, we are ignorant, for we can only examine them by their effects, and even their nature is equally obscure. We find, if we examine organized bodies, that all these principles are capable of being produced through the medium of life; for nearly all animals have the power of evolving heat; many insects, moreover, can voluntarily emit light, and the property of producing electricity is well evinced in the terrible shock of the electric eel, as well as in that of some other creatures.

(2.) Their weight is inappreciable by the most delicate balances, and hence they have been termed the imponderable agents; a property in which they all agree, and in numerous cases appear to be singularly and intimately connected with each other.

(3.) Electricity is the only one which we have particularly to treat of in this work, and this subject is subdivided into several departments, as, electricity of tension, or frictional electricity, where the effects of electricity derived from the electrifying machine are considered; thermo or steræo-electricity, where it is derived from solid bodies through the agency of heat; animal electricity, from organized bodies; magnetic electricity, from the natural or artificial magnet; and voltaic or galvanic, where it is obtained from the voltaic pile.

(4.) Although these names, from their multiplicity, may tend to confuse, be it remembered, there is but one electricity which thus manifests itself in such different ways, either under varying circumstances, or from differences from whence it is derived. Our enquiry will not extend into all these details, but simply into its effects when obtained from the voltaic battery.

(5.) The phenomena, to which the name of voltaic or galvanic electricity has been given, are those which arise from the voltaic or galvanic battery, so named from its discoverers, Volta and Galvani. They found that two pieces of metal, possessing different facilities for combination with oxygen, produced, when properly united, singular convulsions in a dead frog; and following out this experiment, they constructed the battery, which has now, from the improvements of later discoverers, become so powerful and valuable an instrument.

(6.) Without pursuing in detail, the interesting experiments of subsequent authors, it must always be borne in mind, that to make a galvanic battery, with advantage, two conducting substances must be employed with a compound conducting fluid intervening, capable of being decomposed; and the first substance should have the strongest possible affinity for one element of the fluid, and the second substance the least possible affinity. Thus, in a simple circuit, composed of zinc, silver, and water (the water being rendered a good conductor

by the addition of acid) zinc has a very strong attraction for the oxygen of the fluid, whilst silver has a very slight attraction; and therefore a powerful current is generated.

(7.) With regard to the relative conducting powers of bodies, the metals, and all the varieties of carbon, excepting the diamond, hold the foremost rank among solids. The fluids are generally imperfect conductors; none more so than pure water; though in combination with the acids, pure alkalies, or any of the salts, it forms a good conductor. Fused chlorides and iodides are also good conductors. The metals are conductors in the following order; silver, copper, lead, gold, brass, zinc, tin, platinum, palladium, and iron.

(8.) If we except the earthy and alkaline metals, as potassium, sodium, &c., zinc has by far the strongest affinity for oxygen; and on this account is invariably used as the electro-positive metal (the term applied to the metal which is acted upon by the solution, or which in reality acts on the fluid.) All other metals, in any *acid* solution, are electro-negative to them; the term used to imply the opposite state to electro-positive. The following table shows the state of electricity in which the metals stand, with regard to each other, in acid solutions, where every metal is positive to all below it, and negative to all above it. This series relates only to acid solutions, for it varies with almost every solution used:

Potassium	Iron	Silver
Barium	Bismuth	Palladium
Zinc	Antimony	Gold
Cadmium	Lead	Charcoal
Tin	Copper	Platinum.

This order appears to me to require to be again made the subject of experiment; I would suggest that for this investigation, every metal should be used in a finely divided state, similar to the finely divided platinum of my battery.

(9.) When a metal which acts slightly upon a fluid (as for instance, copper) is brought into contact with another metal, which has a stronger affinity for the oxygen of the fluid, the

latter, or electro-positive, is dissolved, and gives a negative tendency to the former, which in that state does not act at all upon the fluid, but is preserved by the latter. Of this singular property Sir H. Davy took advantage, for the protection of the copper sheathing of vessels, which was effectually preserved from decay by pieces of zinc or iron placed in contact with it under the water; but then unfortunately the copper, ceasing to be deleterious, did not prevent the adhesion of marine animals and vegetables, which accumulated to such an extent, as materially to impede the ships' progress through the water. In this way, zinc protects all the less oxidable metals, when pure; but if the electro-negative metals be contaminated with charcoal, or with a metal having less affinity for oxygen, they will still be acted upon.

(10.) The converse of this observation applies to the electro-positive metal, as the zinc; for when pure it is not acted upon by the sulphuric acid, till contact be made with some other metal, having less affinity for oxygen: If it contain any electro-negative metal, however, it will not only be acted upon by the fluid for the generation of the galvanic current, but independently of this a great waste and expense will be incurred. This additional wasting is termed local action, and should be avoided in every possible way.

(11.) Local action, arising as it does from either the zinc or the negative metal, being contaminated with some other metal, is to be considered as an infinity of small batteries, the action of which is quite independent of the great battery; where the hydrogen is entirely transferred to the negative plate, and where consequently no apparent action is visible at the positive plate.

(12.) It is for this reason that the pure metals are exceedingly difficult to dissolve, particularly if the acids be also pure; as for instance, pure silver in pure diluted nitric acid, or pure zinc in dilute sulphuric acid; because there is no local battery of different metals established to favour the solution.

(13.) A battery, in an acid solution, when put into action, exhibits apparently no change at the electro-positive metal, or zinc, if the local action be destroyed; although in fact it is the zinc which is being dissolved. On the contrary, the electro-negative metal, which is in reality undergoing no change, exhibits a copious disengagement of gas, which arises from the transferrence of the hydrogen to that plate, while the oxygen is all absorbed by the zinc.

(14.) This leads us at once to the proximate cause of the voltaic current; for it is found that the amount of action on the zinc is exactly proportionate to the quantity of electricity produced; hence, zinc appears to be the fuel of the battery, holding the same place as coals in a fire. From these and various other facts, Dr. Wollaston, Dr. Faraday, and with them most of the present experimenters in this country, believe that the chemical action of the acid solution on the zinc, or rather of the zinc on the water of the acid solution, is the source of the electric current in the voltaic battery; and this is termed the chemical theory of the pile. The Germans again, and others, following Volta, believe that the chemical action is the effect of the electric current, and that the power is produced by the contact of two dissimilar metals; and this latter has received the name of the contact theory.

(15.) In opposition to the Contact Theory, Dr. Faraday has described in the Philosophical Transactions, curious instances, where the connection of a simple battery, excited by dilute sulphuric acid, was not made through any metal whatever; but through a liquid capable of being decomposed by the stronger energies of the dilute sulphuric acid. He found that a solution of iodide of potassium was best adapted to show this interesting fact.

(16.) Which ever theory be adopted, the use of the negative metal is by no means apparent; for the quantity of electricity developed, cæteris paribus, is exactly as the surface of negative metal exposed; thus, provided there be no obstacle to over-come, if the surface of this be doubled, the quantity of

electricity will be likewise doubled. However, the extent of surface of the positive metal, within certain limits, is not of so much consequence, although too great a deficiency of this is attended with detriment.

(17.) One circumstance must be noticed, that every point of the negative offers a radiating point to the positive metal; for every point not so situated, is much less active, and sometimes even perfectly inactive. In different cases, this property is shown more or less strikingly; for if the hydrogen be removed in its nascent state, it will, under the combined action of its adhesion and elasticity, manifest itself at a great distance from the positive metal, and even quite without the sphere of its radiation, as is the case where the back of a piece of metal is active, while the front alone is opposite to the fluid. When very smooth metals are used, it will also pass to a great distance; but when a metal is prepared in the manner I have hereafter to point out, by platinum, the gas will only be given off from a small extent, though very violently, when touched by the point of a fine zinc wire.

(18.) A relation exists between the power, and the distance interposed between the electro-positive and negative metals; for the nearer these can be brought together, the greater the quantity of electricity developed; though the intensity is not influenced by the difference of arrangement.

(19.) The function of the acid solution has already been partially explained; for we have before mentioned that the water is decomposed, the hydrogen being evolved at the negative metal, and the oxygen combining with the zinc, to form oxide of zinc. The acid now comes into play, and in addition to its adding considerable conducting power to the solution, it removes the oxide to form the sulphate of zinc.

(20.) Whatever exciting fluid is employed to charge the battery, its efficacy depends upon the same principles; but the intensity varies with each variation in the foreign body placed in the water; thus dilute nitric acid, dilute sulphuric

acid, or a solution of salt, all impart different intensities to the battery; an increase, however, or diminution in the proportion of these, does not interfere in the intensity, though the quantity is materially altered; for if but ten drops of dilute sulphuric acid are placed in a gallon of water, the intensity would be the same as if a pint of acid were employed; but the quantity in one case would be infinitely less than in the other.

(21.) A galvanic battery exhibits two important properties, quantity and intensity. Quantity depends directly upon the size of the negative metal or strength of the solution, while intensity depends upon much more hidden causes. Quantity requires but one cell, and this has been referred to in all the preceding experiments, for we have seen that we must have two metals with an intervening fluid. These will remain inactive while they do not touch; but as soon as contact takes place, either in the exciting fluid, at a distance, or through a fluid of more easy decomposition than the exciting fluid of the battery, the action immediately commences. The contact may be made through a great length of wire, with the same result. In this case, however, if the wire be either long, of small diameter, or of a metal of no great conducting power, it will be seen that the hydrogen evolved from the negative metal will be materially lessened, showing that an obstacle is presented to the electric fluid; but if intensity be given to the fluid, then the hydrogen will be evolved as freely as before.

(22.) To obtain this intensity we must have recourse to a number of galvanic batteries, arranged as a series; that is, the zinc of one battery connected with the silver of the next, and this in regular continuation, leaving the extreme zinc and silver free. In this way a hundred batteries may be conjoined, but no more quantity obtained; for only the same amount of electricity passes as when one cell is used. Now, however, this same amount can pass through a much greater resistance, for it would seem as if at every alternation of the

battery, the electric fluid obtained a push to overcome any obstacle afforded to its passage, and this push is called its intensity.

To the beginner, these two properties are very difficult to understand, but perhaps a rough idea may be formed of them by comparing quantity to the piston imparting motion to a railway train, which moves readily with one engine on a level road; let the train meet an obstacle, as an inclined plane or a hill, two, three, or 100 engines may be required to move this same train over, and yet the piston which turns the wheels of the carriage would move no more times than if one engine had been employed.

(23.) There is no advantage, but even a loss, in using a battery with an intensity more than sufficient to overcome a resistance; whether produced by a fluid to be decomposed, or by any other means; for if ten cells arranged as a compound battery be sufficient to overcome the obstacle, the effect of sixty cells, arranged as six tens, would be six times as much as if a single ten were used, because they would then form a battery of six times the size, but of the same intensity as before; but if the whole were used as one compound series, the resulting decomposition would be considerably less than six times the quantity, and to use a battery with advantage this fact must be borne in mind. If again, the surfaces be increased before sufficient intensity be obtained, in like manner it will not add a proportionate amount of power.

(24.) A compound galvanic battery, or one of many cells, has the same quantity of electricity passing in each cell, and therefore the same quantity of zinc dissolved. On this account the fewer the cells that can be employed to overcome the obstacle, the greater will be the economy. It is obvious therefore, that as soon, as by increasing the series, sufficient intensity has been attained to overcome partially the resistance, quantity should be sought by increasing the surface; for when one cell, as a single series, requires one pound of zinc to do a given

amount of work, when that same work is done more quickly by twelve cells, twelve pounds are dissolved—one pound in each cell; and of whatever size the cells may be, still the result will be the same, for no more zinc will be dissolved.

(25.) The simplest form of compound battery is the Couronne des Tasses, which is composed of alternate slips of zinc and platinum soldered together; the zinc is to be placed in one glass, the platinum in the next; and the series, thus arranged, may be charged with dilute sulphuric acid; care must be taken that the metal of the alternate pairs do not touch in the fluid.

(26.) When intensity alone is required, a large number of small plates should be used, as in De Luc's column, which is constructed of pairs of plates of dissimilar metals, separated by paper. There are several methods by which it may be made; the most common of which is to place alternate discs of silvered paper on similar discs of zinc, taking care that the series (i. e. the relative position of zinc) has always the same direction. It may be also made of discs of silvered or gilt paper, the uncovered side having been first spread over with the black oxide of manganese and honey. However, care must be taken that the manganese be not exposed to the sun; as in that case it is rendered inert; and also that the silver or gilt paper be not covered with any varnish, as that which is usually sold in the shops; 500 to 1000 discs must be employed to make an efficient instrument.

(27.) The larger batteries, which were in use for a number of years, consisted generally of copper and zinc, arranged in different forms, according to the fancy of the operator. Thus, the copper of each cell surrounded the zinc, and both were united to fit into a porcelain trough, with eight, ten, or more cells. Here each cell is to be considered as a distinct battery, although the copper and zinc of the whole trough are united, an arrangement contrived to remove the series of batteries from the trough at one time.

(28.) In this compound battery, a porcelain diaphragm

separates each simple battery; but Dr. Hare discovered that a series of batteries might be placed in one vessel, provided that the metals of each battery did not touch in the fluid, and that neither the electro-positive metal afforded a radiatory power to the electro-negative metal, of any other but its own pair, nor that any electro-negative metal radiated in a similar manner to any electro-positive metal. This form of battery is very little known in this country, and I believe but seldom used any where.

(29.) There is another form which was devised by Cruikshank, and which consists merely of square pieces of zinc and copper, soldered together, and fixed at regular intervals in a wooden trough; the zinc always being in one direction. In this battery the metals themselves divide the cells.

(30.) There are many other forms of compound batteries, which do not require particular mention, as the principles which have been already explained, affect them all.

(31.) Provided the metals be sufficient to carry the current, their thickness does not influence the quantity of electricity, that depending upon the surface exposed to the fluid; but if the metals be so thin that they cannot carry the electricity, a diminution in the quantity of the current produced will ensue, similar to that which arises from thin wires. For this reason, earthenware, coated with platinum was not found to answer for the negative plate of a Grove's battery, the platinum surface not being of sufficient thickness. Yet, however thin a metallic or good conducting surface be employed, the current will gradually traverse it; a property of no small importance for the electrotype.

(32.) As the metals are good conductors, and the metallic oxides non-conductors, it is important that the negative metal should expose a clean metallic surface, or else it will be perfectly inert; therefore, when the old forms of batteries are employed, the copper should be thoroughly cleansed from oxide, before the battery is put in action.

(33.) When the metal is thoroughly cleaned before it is

employed, it still very speedily, in fact, almost instantaneously, loses its power. Now this depends principally, if not entirely, in a single battery, upon the hydrogen's adhering to the negative metal, which thereby becomes coated with a non-conducting surface of hydrogen, and is therefore rendered inoperative. The state of surface influences this adhesive quality.

The reader may readily convince himself of the truth of this. Let him immerse in a tumbler of dilute sulphuric acid, a polished plate of copper, and then place a piece of zinc in contact with the copper below the surface of the fluid. Bubbles of hydrogen will speedily appear upon the surface of the copper, and will soon cover its entire surface. It will be seen that these bubbles, instead of rising to the surface, and escaping as soon as formed (or in other words being evolved) will continue adhering to the metal. This depends upon the principle called heterogenious adhesion, which can only operate when the surface of bodies are brought into very close contact. A smooth surface of metal favours the adhesion of the gas to such an extent, as to counterbalance the force with which it tends upwards to the surface of the fluid. This, considering the difference of specific gravity between hydrogen and water, can by no means be a trifling force. Mechanical roughning by sand paper, obviates in some degree this annoyance, but is by no means entirely a remedy. The mode of overcoming this adhesion will be treated of when we describe my battery. To give an idea of the amount of hydrogen which will adhere to smooth metals, I have frequently seen platinum, the heaviest of all substances, rise, by the force of the hydrogen, to the top of the water, after it had been in contact with zinc.

(34.) The same observations apply to the positive metal; for if even impure zinc be polished, the hydrogen will yet adhere to such an extent, that scarcely any action will take place till the surface is corroded; when it will immediately become violent. There is another mode, however, of over-

coming this local action, which has been adverted to in this place, instead of mentioning it before, because I believe its action depends upon the facilitating the adhesion of hydrogen; this mode is the amalgamation of the zinc by mercury. In making a battery, this should never be neglected from its economy, as but a small quantity of mercury is required. It is effected by acting upon the surface of the zinc, either by acid, or by planing the oxidized surface, and then rubbing it with metallic mercury. Let us never forget to whom we owe this discovery, which of itself enables galvanic batteries to be used extensively in the arts. Ages to come will perhaps have to thank the inventor, whom we are too apt to forget because he was neither on the council of the Royal Society, nor a London Professor, yet still the obligation from the public to Mr. Kemp is the same.

The explanation which I have ventured to give of this valuable improvement is the following; the mercury envelopes the small portions of charcoal and foreign metals, and therefore the first gas evolved, adheres so firmly to these, that every foreign point of metal becomes coated, so as to prevent farther action; for of all the metals known, there is none to which the hydrogen sticks so firmly, as to mercury. A very instructive experiment proves that the absence of action depends on the adhesion of the hydrogen; for if mercury with zinc dissolved in it, be placed in dilute sulphuric acid, it will give off no gas, but will be covered with large bubbles; but if a little sulphate of copper, nitrate of silver, or nitro-muriate of platinum be placed in the acid, an instantaneous change ensues, for the hydrogen has not now to be evolved, but is absorbed in the nascent state, to reduce the oxides of these metals.

(35.) In an elementary treatise it is unnecessary to enlarge upon these views, but those desirious of entering into them can consult the Philosophical Magazine for April 1840, or the Transactions of the Society of Arts for that year. An observation of these facts led me to construct the Chemico-

mechanical battery, of which we shall speak after we have described the other forms. Before, however, entering upon that subject, there is still another property of metals which has not been adverted to; viz. that the least oxidable metals, as platinum, in common with the metals which have most affinity for oxygen, become coated, or so infilmed with air, that they are rendered useless, because they expose a film of badly conducting substance to the fluid instead of a metallic one. The film may be instantly destroyed by heat, or by strong nitric acid. This fact has been long known, and the familiar experiment of causing iron filings to swim, while magnesia, which is an impalpable powder sinks, is an example. But I believe it had not been noticed, as influencing galvanic effects, till mentioned in the paper before quoted.

(36.) The mode in which the hydrogen is evolved, influences the intensity of the battery; for if removed from the negative metal in the nascent state, by any substance which readily yields oxygen to combine with it, the intensity is greater than when it is evolved. The cause of this is not exactly known; some supposing that it arises from chemical action at both poles of the battery, whilst others explain it by supposing that the hydrogen carries off a certain portion of electricity of tension, as they find that a gold leaf electrometer is affected, when brought near the evolved hydrogen.

(37.) No farther improvement was made in the galvanic battery hitherto described. All previous alterations being as to size or form; as flat cells, round cells; or as to the arrangement of the metals, as to which should be innermost; but these can scarcely be called improvements. At length Professor Daniell turned his attention to the subject, and produced a battery on a principle altogether new.

(38.) The form of battery which he recommended, was from eight inches to two feet in height, and four inches in diameter. The outer vessel is to be made of copper, of which the external part may be painted, as it plays no part in generating electricity; while the inner remains uncoated. Into this cylinder a

solution of sulphate of copper is to be poured, instead of the dilute acid used in previous batteries; but now, if a *zinc* plate were put into this solution, and contact were made, the copper of the solution would be reduced upon the zinc, as well as on the outer cylinder; and thus the battery would cease to have any effect. It therefore became necessary to enclose the zinc in a porous vessel, in order to separate it from the sulphate of copper. This was effected by a piece of the gullet of the ox; and into this, which forms an inner vessel, the zinc, with dilute sulphuric acid, is to be placed. Thus we have an outer copper cylinder with a solution of sulphate of copper, and an inner vessel containing zinc and dilute acid. As soon as contact is made, the zinc is dissolved, and sulphate of zinc is retained in the inner part of the vessel; whilst, instead of the hydrogen being evolved at the negative metal, it reduces the copper from the sulphate of copper. The inner vessel must be looked upon as a disadvantage, because there is no doubt that it lessens the power of the battery. The more porous this vessel is, the greater is the quantity of electricity developed; and so common brown paper, coarse canvass, and porous earthenware tubes are employed, instead of the bladder, or the lining valve of the gullet or intestines, as formerly. Professor Daniell uses for his positive metal cast zinc rods, which he amalgamates; and as a little copper always passes through the porous vessel, this should be repeated every time it is employed. The earthenware tubes immediately after use should be plunged into water, and there kept till all the sulphate of copper is dissolved out; or else, by crystallization it will sometimes disintegrate the vessel.

(39.) Many have thought that the zinc being two inches apart from the copper is too far, and they have used cylinders which approached a great deal closer; but although there is no doubt that by these means increase of power is obtained, yet many more inconveniences attend their application than the employment of the form originally suggested by Professor Daniell. In the use of porous tubes of every sort, whenever

the reduction of a metal takes place, care must be taken that neither of the plates of the battery touch the porous vessel; for otherwise the reduction of the metal will take place upon it, and at length a line of continuity will extend from one to the other. Candidates ever anxious to obtain the fame of a new invention, made the batteries square, oblong, paralellopiped, and even in many other forms, without any real advantage, for all the alterations attended with benefits one way, have counterbalancing disadvantages.

(40.) This battery is principally valuable for its constant effects; that is, for the power which it possesses of generating exactly the same amount of electricity for a long time together; and for this reason it is extremely valuable in many experimental researches.

(41.) To obtain its constant effects however, certain precautions are required; for if the size of the wires used for the communication be altered, or their length either materially increased or diminished, then will the quantity of electricity vary. The distance between the poles, and also their size, must remain the same; and great care must be taken that the porous tubes be of the same texture; for it is to be remembered, that if but one bad earthenware tube be used in a battery of large surface, the quantity of electricity will be influenced throughout.

(42.) Much misunderstanding has arisen from the use of the term constancy; it is often thought to signify long-continued action, whereas these properties are really different; for a battery may be constant, but only remain in action for a short period; and again, a battery might continue in action for years, and not be constant in its action; the property of long continuation however, is by far the more valuable.

(43.) The principal disadvantages of this battery are, first, the length of time required to set it in action; secondly, the trouble and expense attending the use of the porous tubes; and lastly, the necessity of continually re-amalgamating the plates.

(44.) The essential advantage which this excellent battery possesses over all which preceded it, is the removal of the hydrogen, instead of its evolution at the negative vessel, whilst in the nascent state, by its decomposing the sulphate of copper. It is owing to this also, that this battery gives off no fumes. To employ the decomposing effects of this battery with the greatest advantage, a series of ten or twelve is required.

(45.) Another battery, upon precisely the same principles, although applied in a very different way, was invented by Mr. Grove. He uses, for his negative metal, platinum, and in the inner cell he puts strong nitric acid, and in the outer one, with the zinc, dilute sulphuric or muriatic acid. The form which Mr. Grove prefers, is a many-celled trough like the Wollaston's, with flat paralellopiped porous tubes in the interior; and as platinum is an expensive metal, he takes care that the whole surface is brought into full operation, by completely surrounding it with zinc. In this battery the nitric acid is decomposed by the hydrogen, and deutoxide of nitrogen is evolved; which, coming in contact with the atmospheric air, is converted into nitrous acid.

(46.) This battery is remarkable for its intensity; a series of four being sufficient for most decompositions. A large series exhibits the arc of light in a very brilliant manner; for showing this phenemenon it exceeds all other batteries. This battery however, with its great intensity, is not without some serious disadvantages; for the nitrous fumes which are evolved during its action, are extremely pernicious to the animal economy; so much so, that it might be even dangerous to be exposed to them, without a free access of air. These nitrous fumes will attack almost every metallic surface with which they come in contact; and therefore this battery should not be employed in a room where there are polished stoves or metallic apparatus. The nitric acid moreover passes through the porous tubes, and attacks the zinc to a considerable extent, independently of that zinc which is dissolved to generate electricity:—and lastly,

it has the objection of requiring the trouble and expense attending upon porous tubes.

(47.) We have thus seen that Mr. Grove's intense battery is in its principle similar to that proposed by Professor Daniell, for in both the hydrogen is removed by chemical means; in the first instance by nitric acid, and in the second by sulphate of copper. Of course there are many other modes by which the same results may be obtained; as for instance, by using nitrate of silver, or the salts of gold, palladium, and platinum, or by other oxygenated acids, as the iodic, chloric, and bromic. I have tried many other substances upon this principle, but have not arrived at any new result, nor have found any arrangement superior for its intensity to that of Mr. Grove.

(48.) In conducting a series of experiments on the ferrocyanuret of potassium, having had frequent occasion for the use of a galvanic battery, I found, that although the two last were admirably contrived instruments, yet that it was very desirable to possess one that could be set in action at a moment's notice, and with comparatively little trouble. It became thenceforth my endeavour to construct one that should require little or no labour in its employment, and this was followed by the devising of the chemico mechanical battery.

(49.) This battery, after I had minutely investigated every property which belongs to the metals of which batteries are constructed, was made upon noticing the property which rough surfaces possess, of evolving the hydrogen, and smooth surfaces, of favoring its adhesion. Thus whatever metal we use for our negative plate, we take care that it be roughened, either by a corrosive acid, as iron by sulphuric acid, copper and silver by nitric acid, or mechanically by rubbing the surface with sand paper. Even by these means alone the metals are rendered much more efficient; but to take advantage of this principle to the fullest extent, I cover platinum with finely divided black powder of platinum, by galvanic means; that is, I place the platinum as the copper is placed

in a Daniell's battery; but instead of employing sulphate of copper in the outer vessel, I use a small quantity of nitro-muriate of platinum, so that the finely divided metal is thrown down on the sheet platinum, previously roughened by sand paper. In this way it was also placed on palladium, silver (roughened by nitric acid), plated copper, iron of every sort, and on charcoal, with the same good result; but no other metal was found to answer for its reception. The metal generally employed is silver, because of its cheapness, and its not undergoing any alteration. But whatever metal be used, the principle is the same, viz. the affording a surface to which the hydrogen shall not adhere, but from which it shall be evolved; and the infinity of the points which are presented by such a surface as above described, appears to be the cause of this excellent result. The preparation of the silver is now made a separate branch of a trade, and the platinized metal can now be bought ready for use; but for those who desire to perform this operation, a brief description is here added.

(50.) The metal to be prepared should be of a thickness sufficient to carry the current of electricity, and should be roughened, either by sand paper, as in the case of platinum or palladium, or when silver is employed, by brushing it over with a little strong nitric acid, so that a frosted appearance is obtained. The silver is then washed, and placed in a vessel with dilute sulphuric acid, to which a few drops of nitro-muriate of platinum are added. A porous tube is then placed in this vessel, with a few drops of diluted sulphuric acid; into this the zinc is put. Contact being made, the platinum will in a few seconds be thrown down upon the surface of the silver, as a black metallic powder. The operation is completed now, and the platinized metal ready for use. However, iron, when thus prepared, is as effectual as silver, and may be sometimes employed with advantage. With this metal, all that is required is to rub a little nitro muriate of platinum over it, and an immediate deposit of the black powder takes place.

(51.) The liquid generally adopted to excite this battery, is a mixture of one part, by measure, of sulphuric acid, and seven of water, which will be found amply strong for all purposes. Where we desire greater intensity, we can obtain it by the addition of a few drops of nitric acid, but if too much be used it will attack the silver. When however, platinized platina is employed, the nitric acid may be used with impunity. The electro-metallurgist will find it advisable to use dilute sulphuric acid, containing only 1-16th of the pure acid.

(52.) Numerous enquiries have been made as to what arrangement is best suited to this battery; but this must depend upon the purpose for which it is employed. For the student's laboratory, the Wollaston trough of twelve cells appears to be best adapted (fig. 7 A); and it should be so constructed, that any number of cells may be employed, independently of the others, as they may be required. The silver being the most expensive metal, the zinc shonld completely surround it, so that the whole of the silver may be brought into action. Where a battery is required to continue in action for a very long time, as for days or even weeks, a larger vessel, to contain more dilute acid, must be used (fig 3 A).

(53.) When we desire to employ a battery for manufacturing purposes, it might be as well in some cases to remove the sulphate of zinc as soon as formed, by means of a syphon tube passing to the bottom of the vessel, while fresh acid is continually supplied at the top; but this is not generally necessary. For these purposes the battery should be so constructed, that any of the zinc plates, when worn out, can be readily replaced. There are many other forms which may be adopted; as the circular, with the zinc outside; or it may be used as a tumbler battery.

(54.) The characteristic of this battery is the great quantity of electricity produced, and its simplicity; moreover it requires but very little trouble in its manipulation. The zinc seldom demands amalgamation, as that will generally last till the metal is all dissolved.

(55.) In using this battery it is important that no salt of copper, lead, or other base metal be dropped into the exciting fluid, as by that means the silver would become coated therewith; the plain consequence being, that a surface of copper instead of that of the finely divided platinum is presented to the fluid. From a want of knowledge of this fact, in some who have used the battery, I have seen the negative metal covered with copper, which finally becoming oxidated, rendered the platinum useless.

(56.) Such is a brief view of the three batteries now in use. Professor Daniell's excellent invention being distinguished by its constancy; Mr. Grove's powerful battery, by its intensity; and my own, by the quantity of electricity developed, and by its simplicity. Neither of these can be regarded as a perfect galvanic battery, for each wants some of the properties of the others; it is to be hoped therefore, that every attention will be given to the further improvement of these valuable instruments, until the good properties of each are combined in one. Which of the three is at present to be preferred, must depend upon the purpose for which it is required; and the choice must of course be left to the operator. For my own part it affords me much pleasure to see that the platinized silver battery has fully answered the expectations which I formed of it. By some it has been too much extolled, by others too much blamed. It has been the subject of experiments not appertaining to it, such as comparing its intense effects when quantity is its characteristic. Notwithstanding the mis-statements on both sides, it has fully stood the test of time, and has been employed by the public in a manner which I had not even hoped. The reason they prefer it for general and especially for manufacturing purposes appears to be, that it does not require the use of porous tubes, nor of the strong acids, and that it does not give off poisonous fumes. It will continue in active operation for two, three, or more days, when a sufficiency of acid is supplied to it.

The zinc frequently demands but one amalgamation; and the time required either for setting it in action, or for maintaining its operation, is comparatively not worth a thought; and lastly, the expense of working it is reduced to the lowest possible amount, being exactly proportionate to the power obtained.

(57.) Perhaps I may be expected to give an approximation to the relative cost of working the three batteries. In mine it is the cost of the zinc dissolved by the acid: zinc + acid + a local action. In the constant battery it is zinc + acid + sulphate of copper + much local action. Each cell of this, to do any given amount of work, would cost about twice as much as mine. In Grove's battery it is zinc + acid + nitric acid reduced by the hydrogen + nitric acid combined with ammonia, formed during the action of the battery + extensive waste of the zinc = about three times as much as mine.

(58.) The construction of all the various forms of galvanic batteries has now been considered, and the principles also on which the peculiarities of each are founded, have been briefly explained; though if this important branch of our subject were to be alone discussed at a length proportionate to its value, this volume would not be sufficient for the interesting and important matter relating to it.

CHAPTER II.

ON THE PROPERTIES OF GALVANIC BATTERIES.

Signs of a Battery in action, 59. Harris's galvanometer, 60. Spark, 61. Voltaic electricity charges in Leyden jar, 62. Phisiological effects, 63. Magnetism, 64—68. Galvanometers, 68—70. Horseshoe temporary magnet, 71—73. Decomposition cell, voltameters, poles, 74—84. Laws of voltaic decomposition, 85, 86. Table of chemical equivalents, 87. Fluid necessary to decomposition, 88. Conduction of fluids associated with decomposition, 88—90. Intensity necessary for decompositions, 91. Electrolysis; Electro-chemical decomposition, 92—98. Daniell's theory, 99. State of the fluid during decomposition, 101. Effect of heat upon fluids, 102. Ohm's formula, 104.

(59.) After describing the various forms of the galvanic battery, we are led to consider the effects which they produce, for these are called the galvanic effects, and the theoretical principle which causes them is termed galvanism.

The sign of a battery in action, is the change going on in each cell of the battery itself. In Daniell's battery it is evinced by a deposit of copper on the negative metal; in Grove's battery, by the evolution of nitrous fumes, and in mine by an evolution of hydrogen. These several actions mark exactly the quantity of current passing; but in the two former batteries, no accurate measure can be readily made, although in the latter, the hydrogen may be collected in one of the cells by means of a glass jar, and the quantity thus exactly ascertained.

This property in my battery is of extreme value to the mechanic and experimentalist, for he can tell at once by the hissing of the hydrogen, whether the connections are all correctly made, and what amount of current is passing, a fact of no small importance when applied to the electrotype.

(60.) The next phenomenon which a battery displays is the power of heating wires of sufficient size to carry the current readily; and by this, the most infusible metals, as platinum, palladium, gold, copper, iron and steel, may be instanta-

neously melted. The size of the wires melted, will depend upon the quantity of electricity developed, while the length will depend upon the intensity of the current.

Mr. Snow Harris has ingeniously taken advantage of this property to make an instrument for measuring the voltaic current. It consists of a fine wire passed through a delicate air thermometer, and the expansion of air shows the degree to which the wire is heated. This instrument is a valueless test, unless both thick and thin wires be used in two experiments, for otherwise but one property of the battery is estimated.

(61.) The next property which a battery displays, is its power of igniting metallic or charcoal points, when joined to the two ends of the battery, and held so that they barely touch, a light is then exhibited equal in brilliancy to that of a little sun. This has been called the spark, and much controversy has taken place among the learned at what distance the spark will pass. Some have asserted that it will pass through some distance; Jacobi, however, considered the distance to be extremely small; but Mr. Gassiot, with that liberality of spirit which alone is a sure test of a man's devotion to science, fitted up 100 series of Professor Daniell's largest batteries, but with them, by the most delicate micrometer, he could not discover that the spark would pass at any appreciable distance, on the contrary this large battery would remain quite inert if the poles were separated by the distance of the thinnest film of paper. In a late number of the Philosophical Magazine, Mr. Crosse has revived the enquiry by stating, that by a very extensive series of water batteries, in his own possession, he has succeeded in obtaining the spark at a short distance. He proposes to enlarge his battery to 1000 cells, in order fully to determine this point.

The spark seems principally to depend upon a combustion of fine particles of metal, and, when charcoal or hard gas coke is used, upon little points of it flying from one pole to another, so that one pole wastes away, and the other increases

till the flame becomes quite encased in a mass of carbonaceous matter. This has always been a serious obstacle to the adaptation of this brilliant arc of flame to practical purposes. The phenomenon of the spark requires intensity for its production: a series of Grove's batteries is best suited for this purpose. Professor Wheatstone, by most ingenious experiments, determined, that the duration of the spark did not last for the one-millionth part of a second.

(62.) The next property evinced by the galvanic battery, is its power of charging a Leyden jar; but this is a property of little importance, and requires great intensity. An extensive series of batteries must be used to effect this object.

(63.) Depending upon the same causes as the last, is the shock; which is a convulsive twitching in the muscles from the intensity of the battery. This singular effect requires generally a series. It is felt only when contact is either made or broken; but if a cut exists in the finger, a small series will illustrate this property.

When we desire to exhibit the effect of the shock upon a dead animal, a pin ought to be run through the skin at the head, and another at its hind leg; every time the poles of a battery are connected or disconnected with these, strong convulsions will take place. If the upper lip be touched with a piece of zinc, and the under part of the tongue with a piece of platinum, or *vice versâ*, a flash of light will be perceived when they are connected, whether the eyelids be open or closed. No explanation can be given of this singular phenomenon. All these phenomena are termed the physiological effects.

(64.) A galvanic battery has the power of producing certain effects which are called magnetic effects, and the supposed principle of magnetism. To describe the term magnetism would be impossible, like galvanism, or electricity, because we are only cognizant of it by its properties. There are but two metals capable of being magnetic, and these are nickel

and iron. The identity of magnetism and electricity has, like all other branches of philosophy, received many important additions from the indefatigable Faraday; but although magnetism is fraught with interest, it will be foreign to the purpose of this work to enter farther into its important details, than to illustrate the effects of galvanism.

(65.) The voltaic current, passing at right angles to a piece of iron, from which it is separated by any non-conducting substance, induces in it the properties which are termed magnetic; for if another piece of iron be now held to it, it will be attracted. The more frequently the same current passes round the iron, the greater will be the power; and for this purpose it is usual to twist wire covered either with silk or cotton round the iron, in order that the same current may pass at right angles a great number of times. When the current ceases, from the connection with the battery being broken, a difference according to the nature of the iron is observed; for if it be the pure malleable soft iron, all magnetism immediately ceases; hence, iron so situated is termed a temporary magnet; but if hard steel is used for the experiment, the magnetism indeed is not so powerful, but it continues for a very long period; hence in this state it is called a permanent magnet.

(66.) A permanent magnet if suspended in such a way that it can vibrate, has one of its poles turned to the north pole of the earth, the other to the south pole; but if a galvanic current be passed round this permanent magnet, in the direction of its axis, the magnet will be instantly deflected at right angles from the current, and upon this principle an instrument has been constructed called the galvanometer.

(67.) The direction in which the needle is deflected, is best remembered by a little device which Professor Daniell describes in his lectures; for by supposing that we ourselves are the conducting wires, and the electric current passes from our head to our heels while we are looking at the magnet, the

north pole will be turned to our right hand. This ingenious device is applicable to every position, provided we are either above, or underneath the plane of the needle.

(68.) Galvanometers are differently constructed, according to the delicacy of the experiments for which they are required. In general it is sufficient to use a needle centered as if it were to be used for a mariner's compass, and a long covered wire is to be passed alternately over and under it, in the direction of the long axis. The two ends of the wire may be connected to mercury cups, to afford a ready means to unite them with the poles of the battery.

(69.) A much more delicate form of galvanometer is constructed by using two needles, so suspended, that the north pole of one is over the south pole of the other.

The polarities are thus neutralized, and no longer under the influence of the earth's magnetism. In this state they are called astatic, and are generally suspended by the finest fibre of silk, so that the slightest voltaic current will act upon them.

It is advisable to allow one needle to have a slight preponderence, in order that the long vibration may not be troublesome. An instrument like this is only necessary for the most minute experiments.

(70.) Another form is termed the tortion galvanometer, because a resistance is afforded by the twisting of an elastic substance. By this we are enabled to appreciate differences in slight currents.

(71.) However useful the instrument may be for all small currents, large quantities of electricity are seldom measured by magnetic effects; but I believe that the right use of the magnet is a very important addition to our instruments for measuring galvanic currents. To estimate the quantity of electricity in any voltaic current, a piece of soft iron is to be bent in the form of a horseshoe, and a good sized covered copper wire is to be wound round it, the two ends being left free for connection with the battery. A piece of soft iron

with a hook attached to it is to be used for the keeper, and the weight which this sustains indicates the amount of electricity.

This instrument is only valuable for comparative experiments; as different results will always be obtained by different magnets, because the quality of iron is found materially to influence the results; but if the same magnet be used, and the wire of sufficient dimensions, and of moderate length, there will be scarcely any appreciable resistance offered to the current; and the relative quantity of electricity evolved, independently of its intensity, can be accurately ascertained.

(72.) Temporary magnets are too frequently made with very thin covered wire, and even great lengths employed. Now in this case, the amount of magnetism induced by any current, ceases to be an exact measure of the quantity of electricity passing, because intensity is required to overcome the resistance afforded to the passage of the current from the wires; and it is from this cause that electro-magnetic engines, possessing, as they do, several magnets, and very often thin wires, require several cells before the current passes at all.

(73.) To give a comparative estimate of the value of this test of the quantity of electricity evolved, and that of whereby the power is estimated by decomposition, perhaps is premature, till the latter mode is fully entered into; but as the magnet requires but little intensity, and that entirely depending upon the size of the wires, it is apparent that one cell of each combination, or form of battery, will suffice for the experiment; if however, the decomposition of water be taken as the test, a sufficient number of cells must be employed, to overcome the resistance; and thus, if many combinations are made the subject of experiment, it will be attended with great cost.

(74.) If the various effects which have been already described are fraught with interest and mysterious obscurity, how much more is the property which the battery possesses, of decomposing various substances, and of overcoming the most

powerful affinities by which bodies are united! To this part of the subject we are again indebted to the labours of which the Royal Institution has been the principal seat, and Sir Humphrey Davey and Faraday the authors, though Daniell and many others have been by no means behind hand in the field of enquiry.

(75.) The decomposing cell is to be reckoned as one of the cells of the battery, with variation in the metals and solution, for the purposes of experiment. Formerly the size of the plates of this cell was reckoned but of little importance, mere wires were employed, but now the plates are made much larger. This fact has been particularly insisted upon by Mr. Grove, and certainly it is a circumstance to be fully attended to.

(76.) There are many forms of the decomposition cell which are useful, according to the purpose for which it is wanted. The simplest is the V shaped tube, which is nothing but a glass tube, bent in the shape of the letter from which it derives its name. A little strip of platinum is to be placed in either part, with the fluid, and these are to be connected, one with the negative, the other with the opposite pole of the battery.

(77.) The next form was devised by Professor Faraday, and is adapted to measure the quantity of gas given off when water is decomposed. To this he gave the name of voltameter, as indicating the amount of electricity passing. Of this form there are many varieties, differing as a small or large quantity of gas is required to be measured. In the former case, two pieces of platinum are fixed about a quarter of an inch apart, and a tube, graduated to cubic inches, is supported over these poles so that the gas may be collected. Sometimes two tubes are employed, one over each pole, the object of which, is to collect separately whatever may be evolved. In other cases, where large quantities have to be estimated, a bent tube passes from the top of the apparatus to a graduated jar, placed in a pneumatic trough. This instrument is made more complicated when the operator is desirous of investigating the changes

which take place in the solution; for then porous tubes of earthenware, bladder, &c. are used to separate the poles, and to prevent the solution on one side passing freely to the other. Substances requiring heat to bring them into a state fit for decomposition, are generally placed in a tube containing two fine platinum wires, which serve as poles, when connected to the battery.

(78.) Having described the usual apparatus to effect decomposition, we have seen that in every case they have, in common, two pieces of platinum, separated from each other, but capable of being connected to either extremity of the battery. These pieces of platinum have the mysterious and incomprehensible names of poles; one of which may be considered as holding the place of the negative metal, and is called the electro-negative pole; and the other, the electro-positive pole.

(79.) However, Dr. Faraday disapproving of the name of poles, has called the electro-negative the cathode; and Professor Daniell disapproving of both, has called it the platinode. These three terms, the electro-negative, cathode, and platinode, are synonymous, and are given to that pole which would have been the metal unacted upon, had it been in an ordinary cell of the battery. The opposite pole, holds the same place in the decomposition cell as zinc in the ordinary battery, and technically has the name of the electro positive, anode, or zincode of the battery.

Dr. Faraday has described the poles, as the passages or doors by which the electricity enters into, or passes out of the solution suffering decomposition. On this account he has given the term of electrodes. Good conductors are the best adapted for poles, and for this reason, metals are generally employed; but poles of water, and even of air, have served this office.

(80.) The metal employed for Faraday's voltameters should undergo no change, either from the solution in which it is placed, or from the elements which may be evolved at its sur-

face; and in this respect, platinum answers above every other substance, for almost all other metals are liable to be oxydized, or even dissolved.

(81.) The greatest confusion has arisen by not considering the decomposition cell as one of the cells of the battery, but refering the effects to the plate of the battery to which the pole is connected. The reason of this is obvious; for when the terminal plates of a battery are connected with a wire, the circuit is completed, and the platinum of the battery is the platinode, electro-negative, or cathode of the battery. When the circuit is completed, by a liquid to be decomposed, the effect is no longer to be attributed to the terminal plates of the battery, but to the plates in the decomposition cell with which they alternate; so that as, the free zinc of the battery is connected with the platinum of the decomposition cell, the name must not be given from the zinc of the battery, but from the platinum of the decomposition cell; and therefore it is the platinode of the battery. The converse of this applies to the extreme platinum of the battery; for as the platinum in the decomposition cell with which it is connected, holds the place of the zinc in the other cells, the platinum being substituted for zinc, to cause the evolution of the oxygen, and to prevent its combination, the name must be given to the platinum in the decomposition cell, which is there holding the place of the zinc, and not to the terminal plate of the battery; it therefore is the zincode, electro-positive, or anode of the battery. Some have given a different explanation of this alteration of the poles, when the circuit is completed, by a solution to be decomposed, instead of metallic wires; they suppose that the two terminal plates in a compound battery, hold no farther place than that of carrying the current; but this will not bear the test of enquiry.

(82.) We have now seen that the decomposition cell, or decomposing apparatus, is nothing but one of the cells of the battery, varied for the purpose of experiment; it necessarily follows the law, that in every cell there is a similar

amount of chemical action. The measure of electricity, by the chemical action, may be made in any other cell; and wherever made, it will indicate exactly the action taking place.

(83.) Of the valne of the decomposition apparatus, or voltameter, it is necessary particularly to take notice. As far as the amount of chemical action passing is concerned, the voltameter is a most valuable test. But if we are desirous of comparing the amount of electricity capable of being generated, by combinations of different metals, or the effects which are produced by differences of arrangement, or the resistance which various substances offer to the passage of the current; then it must be recollected, that if two platinum poles are employed, a strong resistance is offered to the passage of the current, which would materially interfere with the accurate result, unless that be overcome. A want of application of these facts has led many distinguished scientific chemists into singular blunders, and many circumstances have not been appreciated, which would otherwise have been noticed.

(84.) A far better voltameter can be constructed by using one of the cells of the platinized silver battery, and collecting the gas evolved from the negative plate. This apparatus would offer but little resistance to the passage of the electricity, and would thus give more accurate results.

(85.) When we state that the action in each cell is alike, it is not meant that the same weight of metal or salt would be decomposed in each cell, but that one equivalent of some substance is decomposed in each cell; thus, for one grain of hydrogen liberated in one cell, thirty-six grains of chlorine would be liberated in a second; ninety-six grains of platinum in a third, and 200 of gold in a fourth, because these are the chemical equivalents, or combining numbers of each of these separate substances.

(86.) The very term chemical equivalent seems to mark that it relates to something not very intelligible, and unfortunately that is found to be too correct, for this doctrine is found by all

beginners to be exceedingly difficult. However, by granting one supposition, the whole mystery is cleared up; for let us fancy that every elementary body is capable of being subdivided into ultimate atoms, and that the atoms of these are of different sizes and different weights; it will then be apparent that if we group these atoms together to form any compound, we shall require different weights. Thus, if we combine gold with hydrogen, 200 grains of the first would take only one grain of the last, and yet there would be but one atom of each; or if one grain of hydrogen is liberated in the battery, 200 grains of gold would be deposited in the decomposition cell.

(87.) The following is a table of the equivalents of the substances which we shall have to speak of in this work. For our present purpose we may consider them as the weight of the primitive atoms. Thus, if we are able to ascertain the weight of zinc dissolved, of hydrogen evolved, or of the metal reduced, we shall be enabled to ascertain either of the other cases, or how much, either in weight or bulk of any other substance, would have been under the same circumstances thrown down:—

	Equivalent, by Weight.		Equivalent, by Weight.
Hydrogen	1	Silver	110
Oxygen	8	Nickel	28
Chlorine	36	Chloride platinum	132
Potassium	40	Chloride gold	308
Sulphur	16	Sulphate copper	125
Zinc	32	Nitrate copper, anhydrous	94
Lead	104	Sulphate zinc	143
Tin	58	Sulphate iron	139
Iron	28	Nitrate silver	170
Copper	32	Sulphuric acid	40
Gold	200	Nitric acid	54
Platinum	96	Muriatic acid	37
Palladium	54	Ammonia	17

As 100 cubic inches of hydrogen weigh 2 grains and 1-10th, it follows that for every 47 cubic inches of gas evolved from my battery, that 32 grains of copper, 96 of platinum, and 200 of gold, would be reduced; and the equivalent of every other substance would show in grains the quantity thrown down.

(88.) Next to the form of apparatus for decomposition, a description of the laws by which they are influenced follows as a natural sequence, and these have been fully investigated by the labours of Dr. Faraday. All bodies must be in a peculiar state to suffer decomposition, for no solids can be thus acted upon. When fused by heat they very readily give up these elements; as for example, chloride of silver which is decomposed by a single cell of zinc and platinum, excited by dilute sulphuric acid, though no voltaic power will separate them in the solid form.

There are apparent exceptions to this law, as the decomposition of sulphate of lime and baryta, with the addition of water, yet the first of these is undoubtedly moderately soluble. The same perhaps cannot be said of the latter, though probably a little dissolves which is decomposed, and thus the fluid not being saturated, dissolves more, and this is repeated till the whole is dissolved.

(89.) No fluid will be decomposed, unless it be a conductor; thus, pure water which is a very bad conductor, does not yield up its elements; whilst if acids or alkalies be added to it, then it becomes a very excellent conductor, and is easily decomposed. Water may also be made a good conductor by the neutral salts.

As a general rule, fluids will not conduct an electric current, without suffering decomposition, and for this cause, as soon as water is made a good conductor, it is decomposed; and the water does not conduct more electricity than is to be accounted for by the decomposition.

(90.) Some fluids, however, of good conducting power, may have a current of less intensity than what is required for the decomposition passed through them, therefore these two laws,

both developed by Faraday, are not exactly the converse of each other. Examples of the exception to the second are to be found in chloride of lead or fused nitre, which conduct feeble currents without decomposition.

(91.) A certain intensity is necessary to effect decompositions, and this differs with different substances; thus, a solution of iodide of potassium, or fused chloride of silver, yields to a single battery, whilst dilute sulphuric acid and other substances require more intensity to effect the same object.

The following, upon the authority of Faraday, is a short list of substances, in the order in which they most readily give up their elements:—

Iodide of potassium, solution
Chloride of silver, fused
Pro-chloride of tin, do.
Chloride of lead, do.
Iodide of lead, do.
Muriate acid
Water, acidulated with sulphuric acid

(92.) Some bodies suffer decomposition directly, as the consequence of the voltaic force passing; as water, which gives up its elements, hydrogen and oxygen, solely from the elective currents. To this Dr. Faraday has given the term electrolysis, because the elements appear to be rent from their combination directly by the voltaic-force, in contra-distinction to another important property, which will be hereafter mentioned. The elements which are decomposed he has called ions; they are not both evolved at one pole, but one at the electro-positive, anode, or zincode, while the other is given off at the electro-negative, cathode, or platinode of the battery. Those which pass to the first pole, are called anions, those to the second, cathions.

(93.) The poles or electrodes, have no attraction for elementary bodies as long as they are in their simple state, for bodies must be in combination to be affected by the voltaic current. Upon this account, a simple solution of chlorine,

bromine, &c., does not give up these substances to either electrode.

(94.) Those bodies capable of suffering decomposition must contain one equivalent of each element, that is, composed of one of the hypothetical atoms, which I have previously mentioned; (87.) and to this general law but a single exception can be found in the periodide of mercury, which, however, is so unstable a compound, that the slightest exposure to light will cause its decomposition, which alone would be calculated to throw doubt on the validity of the experiment.

Sulphuric acid and phosphoric acids are not themselves electrolytes, that is, they do not directly yield their elements to the force of the battery, because they consist of one equivalent of phosphorus or sulphur to three of oxygen.

(95.) It is not necessary that a substance should be directly composed of elements to enable it to pass to the electrodes or poles; or in other words, bodies composed of compound substances are ions, as well as those composed of simple substances; thus, sulphuric acid, phosphoric acid, arsenic acid, and other acids are ions to the electro-positive pole, or anode, while protoxides generally, ammonia, potassa, and many other substances are ions to the opposite pole. The following is a list of simple and compound ions given by Dr. Faraday:—

ANIONS:

Oxygen	Fulorine	Selenium
Chlorine	Cyanogen	Sulphoganogen
Iodine	Sulphur	Acids
Bromine		

CATHIONS:

Hydrogen	Alkalies,
All the metals	Vegito alkalies, as
Metallic oxides	morphia, &c.
The earths	

(96.) The same substance, under different circumstances, will be evolved at different electrodes; as at one time it may take the part of a base, at another it will perform the function of an acid. A familiar example of this is afforded in the oxide of copper; for when combined with sulphuric, nitric, muriatic, or any other acid, it is evolved at the negative pole, or cathode; whilst, when in combination with ammonia, it acts the part of an acid, and is evolved at the anode or positive pole.

(97.) If we find a body at the pole of a battery, it is by no means certain that it has passed by direct decomposition of the voltaic current; because, if the compound of which it formed a part, was dissolved in water, the elements of the latter being set free, often act in an important way to form new combinations, which thus result from the secondary effects; thus an aqueous solution of a metallic salt, for instance, copper being subjected to a voltaic current, has hydrogen presented at the cathode, and oxygen at the anode. But at the same time this change is taking place, oxide of copper is passing to cathode, and sulphuric acid to the anode. The hydrogen seizes upon the oxygen of the oxide of copper, and forms water, whilst the metallic copper is thrown down on the electrode or pole, not by direct voltaic action, but as a secondary effect, attributable to the hydrogen. Sometimes the elements will combine with the poles or electrodes, forming new combinations; thus, if the poles be easily oxydated, the oxygen will form an oxide, and in the same way if any other substance be presented to the gases for which they have strong affinity, a similar combination will take place. Hence this class of effects, which are far more numerous than electrolytical effects, are called secondary, or electro-chemical decompositions. Sometimes these secondary results are most complicated, and perhaps none more so than the extraordinary one which I have described to take place with the oxygen, on the common yellow ferrocyanate of potash; as this, by combining

with a portion of the potassium of the ferrocyanate, gives rise to a totally new definite salt.*

(98.) The secondary effects of oxygen and hydrogen have been proved by numerous well devised experiments, but still no positive demonstration was obtained, that the hydrogen evolved from the decomposition of water, would reduce the metals with the voltaic current. However, whilst experimenting on the non-metallic elementary bodies, the porous cokes and charcoal were observed to retain a portion of hydrogen, after they had formed either the negative or positive pole of the battery.† When these afterwards were plunged into a solution of sulphate of copper, they became immediately coated with the metal, adding positive confirmation to inductive reasoning.

(99.) Professor Daniell, in a paper read before the Royal Society last spring, has given an entirely new view, as to the mode in which the metallic salts are sometimes decomposed. He supposes that the acid and oxygen pass one way, and the metal the other. From these considerations he has given a new view of the composition of the salts: thus, sulphate of copper, instead of consisting of sulphuric acid + oxide of copper is supposed to be constituted of (sulphuric acid + oxygen) + copper. The two first elements, as they are considered to be in combination, are called oxysulphion, and the salt oxysulphion of copper. In the same way, the radicle of the nitrates is called oxynitrion—of the carbonates, oxycarbion—of the oxalates, oxalion—of sulphovinates, sulphovinion.

In the same paper, another important fact is detailed; which is, the property the electric current possesses, of decomposing two substances in the same solution; thus, both a metallic salt and acidulated water may be decomposed at the same time, the current dividing itself between them.

(100.) We have now seen that substances may be decom-

* Philosophical Magazine for September, 1840.

† Philosophical Magazine for May, 1840.

posed in two ways, either from directly yielding their elements to the voltaic current, when the compound consists of single equivalents, or by secondary action arising from changes which occur oftentimes, as a result of a new decomposition, or combination of the elements of the first substance decomposed upon other substances within their sphere.

(101.) The fluid between the electrodes, whilst decomposition is taking place, apparently has no change; that is, the effects of the decomposition are only manifested at the poles; thus, if sulphate of copper be electrolysed, sulphuric acid passes one way, oxide of copper another; yet neither acid nor oxide can be found in any part intervening. These experiments are best conducted in a long flat vessel with two porous plates which divide it into three departments, of which the two exterior receive the electrodes.

(102. The temperature at which the solution to be decomposed is kept, materially interferes with its conducting power; a fluid which is a good conductor at ordinary temperatures, will scarcely admit the passage of the galvanic fluid at the freezing point, whilst at the boiling point a passage will be afforded with the greatest readiness. It becomes therefore, a very important matter to keep solutions at a high temperature, when we are desirous of effecting much decomposition in a short time, and at a slight expense.

(103.) Ohm, in an elaborate and obscurely worded paper, has given the mathematical formula for the galvanic current. His general formula may be thus expressed. The intensity of action (A) is equal to (the electromotive force (E) multiplied by the number of batteries) (n) divided (by the resistance the current has to overcome, external to the liquid of each battery (r) plus (the resistance encountered by the peculiar arrangement of each cell multiplied by the number of cells (r))).

It would be thus:—

$$A = \frac{n\,E}{r \times n}\,r'$$

Such is a brief account of the leading effects which are called galvanic, with the various properties which are either subservient or detrimental to the voltaic current.

Its application to the arts is one of the greatest improvements of modern times, and although much has been done in this important and extensive field of enquiry, yet this alone suffices to show, that as we progress, the path to be pursued widens and enlarges, exposing to view an immense tract, fertile exactly in proportion to the labour and ability employed in its cultivation.

BOOK THE SECOND.

ON ELECTRO METALLURGY.

CHAPTER I.

ON THE APPARATUS TO BE EMPLOYED FOR THE REDUCTION OF THE METALS.

Electro-metallurgy requires a knowledge of galvanism, 104. The idea of electro-metallurgy, suggested by Daniell's battery, 105. The porous tube or single cell apparatus, 106—112. Capillary tube apparatus, 113. Plaster apparatus, 114. Compound battery apparatus, 115, 116. Single battery apparatus, 117, 118. Precipitating trough, 119. Single cell and battery conjoined, 120. Mason's arrangement, 121. Management of the apparatus, 122, 123. Lines on the reduced metal, how to be avoided, 124. Adhesion and non-adhesion of the reduced metal to its mould, 125—128. Apparent adhesion, 128. Lateral growth of the reduced metal, 129.

(104.) Electro-metallurgy depending essentially on galvanic agency, is subject to the operation of the same principles, and governed by the same laws which have already been laid down in the book which treats of galvanism and galvanic batteries; the successful reduction, therefore, of the metals, must depend entirely upon a thorough knowledge of galvanism, and galvanic apparatus. We should recommend our readers then, before they enter upon this department, to make themselves thoroughly conversant with the contents of the first book; for what operation can be successfully performed without a complete knowledge of the nature of the implements with which that operation is to be performed.

Independently, however, of these general galvanic properties already adverted to, there are certain particular ones

appertaining either to the different metals, or to the different qualities of the same metals, which have to be considered in detail, as well as the apparatus to be employed for precipitations.

(105.) The idea of electro-metallurgy appears to have been first suggested by the use of Professor Daniell's battery, for during its action the outer copper vessel, which is the negative metal, becomes coated with an additional layer of metallic copper; hence, as this new deposit is placed in close apposition to the vessel, a cast is produced. If we call to mind the construction of the battery, we see that it consists essentially of two vessels, the inner being porous, and containing dilute sulphuric acid, while the outer contains the solution of sulphate of copper, and the negative metal.

(106.) If sulphate of zinc be present in a solution of sulphate of copper, the texture of the copper has been described by many authors to be so brittle, as to be crumpled up in the hand. For this reason, the nature of the porous tubes ought to be such as to preclude the possibility of the salt of zinc, which is produced by the chemical solution of the zinc, being mixed with the sulphate of copper. The effect of the salt of zinc in causing the brittleness of the copper, appears from my experiments, to be altogether overrated, and though it would be undoubtedly preferable to prevent, as far as possible, the mixing of the solutions, yet I am not prepared to state that it is of any material consequence.

(107.) The substance best adapted for the separation of the solutions, in an electrotype apparatus, is animal membrane, though a coarse gold beater's skin, from the larger intestine of the ox, or a thin bladder may be used with impunity, provided they are about the same texture. We have already mentioned, in a former part of the work, that the more porous this vessel is, the greater the quantity of electricity developed, and the greater, therefore, the quantity of copper deposited, as the amount of deposit is always in relation with the quantity of electricity generated. The following is the order in which

different substances stand with regard to their capabilities of admitting the passage of electricity:—

Brown paper
Thin plaster of Paris
Gold-beaters skin
Bladders of various thickness
Thick plaster of Paris.

(108.) Of the various forms of apparatus, which may be used for the precipitation of the metals, the most simple is Daniell's battery, having a porous earthenware tube, to contain the acid and zinc, whilst the cast is placed externally to this, and connected by a piece of wire to the zinc. (fig 1.) Thus, for instance, take a pound pot, and half fill it with a solution of sulphate of copper; in this, place the earthen vessel, with the acid and zinc, and this constitutes the whole of the present form of apparatus; for when we desire to make an electrotype, it is only necessary to place the cast in the outer vessel connected with the zinc, and then action will immediately commence. Saturation of the liquid may be preserved by suspending some of the salt in a linen bag over the mould. This form is objectionable, because the salt of zinc speedily passes through to the outer vessel; but it has the advantage of allowing the mould to be placed vertically, in which position it is much less liable to have particles of dust settling upon it.

(109.) There is another form where bladder takes the place of the earthen vessel, and where the position of the cast is horizontal. (fig 2.) Here, the outer vessel, which is square, is made of wood, coated internally with cement; on one part of the edge of which, a piece of brass is fixed, in which are two holes, one for connection with the wire of the cast, the other for that of the zinc of the battery. In the interior of the trough, a moveable shelf of mahogany is placed, on which is supported a glass containing a zinc plate, and crystals of sulphate of copper to be dissolved. The glass has a piece of bladder tied over the rim, and this forms an outer vessel similar to the porous tube in the former apparatus. It in like

manner contains the acid and zinc; the latter being connected by a screw to a wire, in such a way that it can be readily removed. This apparatus is preferable in many respects to that first described; because the sulphate of zinc cannot pass through the membrane readily to the copper, and facilities are offered for changing the zinc and acids, &c. In this apparatus, care must be taken that the mouth of the glass be wide enough to afford a radiating point from the zinc to every part of the cast, as it has been already noticed, that want of attention to this, would be attended with inconvenience. (17.) The only circumstance to be observed is, that the zinc be equidistant at every place from the metal on which the reduction of the new metal is to be effected, so that the deposit may be every where equally thick.

(110.) The solution, in every single cell apparatus, should be acid, and the solution of the metallic salt ought to be maintained in the required degree of concentration, by keeping some crystals of the salt undissolved in the solution. If these crystals are allowed to sink to the bottom of the vessel, they will not answer the intended purpose of maintaining a saturated solution; for the portions of the fluid which have been deprived of their metallic salt, rise to the surface, whilst the saturated parts remain in contact with the crystals at the bottom, thus preventing their solution. This difficulty may, however, be readily overcome, by placing the crystals to be dissolved in a little bag, on a shelf at the top of the liquid, by which means the saturation of the fluid will be ensured.

(111.) Another form might be made by dividing a box into two compartments, by a flat porous slab of earthenware, similar in composition to the porous tubes of a Daniell's battery. Into one compartment the solution of sulphate of copper and negative metal is to be put, and into the other dilute sulphuric acid. The advantage of this apparatus would consist in the facility gained in the manipulation; and for the arrangment of the zinc and copper, so that they may be at every place equidistant from each other—a circumstance of great

importance in the manufacture of large plates, which may thus be accomplished with ease. The porous diaphragm might be exchanged for a more ready but less durable one of plaster of paris, paper, or bladder.

(112.) Other forms may suggest themselves to the operator, for in whatever way a Daniell's battery is constructed, a similar form will equally answer for the electro-metallurgist. (38.)

(113.) An apparatus for very weak currents, I sometimes use with great advantage, when the change takes place at the cathode of the battery. It is made in a very simple manner: the solution to be decomposed, is placed in a tumbler; a piece of glass tube is then drawn at one extremity to a capillary bore. This fulfils the office of the porous tube, and contains the zinc (which in this arrangement is merely a piece of amalgamated zinc wire) and a very dilute acid solution. The quantity of electricity generated by such an arrangement as this, is necessarily very small indeed, for the construction is in every way unfavourable to its developement; first, the diluteness of the acid solution materially lessens the quantity; then, the hole through which the current has to pass is so small that much force is required to blow any liquid through the aperture, even by drops, and therefore a great impediment is offered to the passage of the current. Moreover, a very fine platinum wire is emplcyed to effect communication; and lastly the substance, which is the subject of experiment, is not placed opposite to the capillary hole. The mode in which the capillary tube acts in lessening the current, seems to be by interrupting or breaking the continuity of the fluid, so that but a feeble amount of the current can pass. The regulation of the quantity of electricity can be perfectly effected by regulating the bore of the tube.

(114.) Sometimes, when a very feeble current is required, a glass is filled up at one end with a thick piece of plaster, which fulfils the office of a porous tube. This apparatus was first employed by Dr. Golding Bird. Where we only require to lessen slightly the quantity of electricity, we content

ourselves with extending the distance between the electro-positive and negative metals. In other cases we use a thick bladder or thin communicating wires, and we conjoin the whole or a part of these contrivances for lessening the power.

(115.) In all these cases the metals are precipitated at the negative metal of a simple battery. In like manner, by whatever other method we can render a plate negative, there will the metal be precipitated; and thus, if a battery, sufficient to decompose acidulated water, be constructed with two platinum poles, at one pole oxygen, and at the other hydrogen will be evolved; and at the latter the metal will be precipitated. It has been mentioned before, that one cell of Grove's, two or three of Daniell's, or of my form of battery, will decompose acidulated water between platinum poles; but still, with that degree of intensity only, a feeble quantity of gas is given off. Now where we wish to employ feeble currents, the series just mentioned may be used with great advantage.

(116.) Where we require great intensity, but very feeble quantity, we may use a number of cells, exciting the battery either by simple water, or acidulated with a single drop of acid in each cell. The oxygen, in this method of reducing the metals, is always evolved at the positive pole. (fig 7.) In most cases however, we require to precipitate a large quantity of metal, and then it becomes a matter of importance to effect that object by the smallest series.

(117.) For most purposes the preceding methods are never adopted; but when silver, or any other metal of greater affinity for oxygen is required to be precipitated from its solution, advantage is taken of the affinity which the metal has for the oxygen; and instead of using a platinum pole at the oxygen end of the battery, we employ a piece of metal of the same nature as that which we wish to precipitate, which performs the functions of the positive plate or zincode in the trough. As the solution of metallic salt is continually depositing its metal, the piece which constitutes the positive pole is dissolved

by the acid and oxygen which held the reduced metal in solution, and the liquid is thus kept continually saturated. One battery is amply sufficient for this mode, for there is but little resistance to overcome. (fig. 3.) (fig. 4.) (fig. 6.) A series of precipitating troughs, arranged like a compound battery, may be employed occasionally with only one battery.

(118.) To illustrate this method, let us suppose that we have to take a cast in copper. A solution of a salt of copper is to be placed in a convenient vessel, and the object on which the precipitation is to take place, is to be connected with the zinc of the battery, whilst a piece of sheet copper is connected with the silver. As soon as action commences, water is decomposed, oxygen passes to the copper pole and oxydizes it, and the hydrogen passes to the negative plate. Whilst the decomposition is taking place, oxide of copper is passing to the negative pole, and the acid to the positive pole; the hydrogen reduces the oxide of copper at the negative plate, whilst the acid combines with oxide of copper at the positive end, and thus the saturation is continued.*

(119.) The apparatus used as a precipitating trough, must vary in shape, according to the size and form of the object to be copied, and the solution according to the metal to be thrown down. (fig. 3, b.) (fig. 4, b.) (fig. 6, b.) (fig. 7, b.) These will demand a particular description; but here we must say a few words as to the materials best adapted for this vessel, viz. the precipitating trough, and certainly glass is preferable in all respects, excepting its brittleness and its expense; these two qualities rendering it much less generally applicable than it would otherwise be. Porcelain of some kinds, such as Wedgewood's, &c. is found to be equal to glass, possessing its unalterable properties. However, even this is too expensive and we have recourse generally to the common earthenware. Doubtless many will be

* It has been mentioned before, (99.) that Professor Daniell has given a different theoretical explanation of these decompositions, though practically, the change taking place is the same as here given.

astonished, at being informed that most metallic substances will penetrate through the glazing, into the very heart or biscuit of the jar, and freely pass to the exterior of the vessel. This may be thoroughly prevented by coating the interior with pitch. Wooden vessels are even more frequently employed than these, because they admit of great variety of form, and can be rendered completely water tight, by a cement composed of bees' wax one pound, rosin five pounds, red ochre one pound, and two table-spoonfuls of plaster of paris. A common tin trough, or a leaden vessel will answer, but the interior must, in like manner, be coated either with cement or pitch. One advantage of the latter is, that the salt in solution has but little tendency to crystallize upon it, which in other cases would be a very troublesome property; for occasionally the whole of the salt from a solution will pass to the outer part, which will thus be covered with crystals.

(120.) Another form of apparatus may be employed occasionally with advantage; when we require a considerable intensity, and do not wish to incur the expense of a large series. It is a union of the simple apparatus and the battery. In the decomposition cell we have a porous tube, containing the acid and zinc, and in the outer part we have the solution to be decomposed. The zinc is to be connected with the silver of the battery with the negative plate in the decomposition cell, and thus the circuit is completed. It is manifest that this apparatus increases the intensity; as by using zinc at the positive pole of the decomposition cell, but little impediment is offered to the electric current.

(121.) There is yet another mode by which we can precipitate the metals with the utmost cheapness, though the length of time required is very much increased by the process. We use here the Daniell's battery apparatus, or simple cell for the reduction of the metal; but instead of connecting the zinc with the negative metal at once, we make that zinc and metal a battery, to be connected to another decomposition cell. In this we have a second piece of metal as a negative plate, and

a piece of copper as the positive plate. The metal is connected with the zinc of the first cell, and the copper with the metal. In this way, with one pound of zinc we obtain two pounds of copper. The application, however, of the second cell affords an impediment, and therefore the porous tube in the first cell should be as thin as possible. This very ingenious apparatus was devised by Mr. Mason, but has not been much used, because it has not been sufficiently known.

(122.) The whole management of the precipitation of metals, depends for its success not only on a right knowledge of the principles of quantity and intensity, but also on a right application of them. The latter property does not influence the result, as we shall hereafter see, so much as the former, but in most cases this should be rather abundant than deficient. The intensity, so far as regards the electrotype, may be increased in three ways; by increasing the series, by using exciting liquids, capable of giving greater intensity, or which is by far the best, by using the fluid in the decomposition cell, in that state which most favors the convexion of the current. The quantity of the current may be increased by enlarging the size of the negative plates of the battery, by increasing the strength of the acid solution, by using a larger anode, zincode, or positive pole in the decomposition cell, or by diminishing the distance between this and the negative plate. Each of these, separately, are quite sufficient to regulate the quantity of electricity passing. The one which I generally employ for the precipitation of most metals, is the increase or diminution of the positive pole; sometimes I reduce this to a fine wire, immersed not more than one-tenth of an inch in the fluid.

(123.) To ascertain the exact quantity of electricity passing, a galvanometer must be employed, especially for very feeble currents; but if my form of battery be used, the operator can judge with sufficient accuracy of the quantity of electricity passing, from the evolution of hydrogen from the negative plate. All instruments are incumbrances to the practical mechanic, and I believe that no workman would require any-

thing farther, if my battery be used, than the ocular or aural test which the hydrogen affords.

(124.) The position of the substance upon which the metal is precipitated, causes, in certain cases, a very singular phenomenon in the deposit; for if it be placed vertically in the apparatus, or especially if the upper part overhang the lower part of the plate a series of lines will be produced, amounting, in some cases, to grooves of an inch in depth. The cause of this is easily discovered, if the solution be watched whilst the battery is in active operation, it will then be seen that as the hydrogen reduces the metal from the fluid, it directly becomes colourless, and lighter than the surrounding solution. It cousequently rises and causes a current, which, like a stream, is reflected in various ways, at every elevation or obstacle. Having once made for itself a channel, it keeps to it, and increases till the lines become of the depth which I have mentioned. This prevents the deposit being of uniform thickness, and makes the plate valueless. It may however, in a great measure be obviated, by giving the plate a slight inclination, or this tendency may be entirely destroyed by placing it horizontally. When the deposition is very slow, these lines are not seen.

(125.) The new deposit of metal may sometimes be removed with the greatest facility, at others it adheres with such firmness as to form one metallic mass, with its mould, from which it cannot be separated by any means whatever. Now we require both these properties for different purposes, and though heretofore the results have been too much the effect of chance, doubtless it is a matter of the greatest consequence to have such a control over the process, as to obtain, with certainty, either, as we may happen to require them.

(126.) The adhesion of the original and duplicate is termed, technically, *buttoning down;* the non-adhesion has not been, as yet, vulgarly christened. Both depend on two facts, the enfilming of metals by air, and the possibility of that becoming a pole. (35.) These properties have been fully entered into in

the first book, but here we have to notice their practical application. If a piece of smooth metal be plunged into water, it will resist wetting, and in that state is to be used, when we do not wish the deposit to adhere to its mould. In order to take advantage of this property, the plate is to be dipped into the solution, and the circuit immediately completed. The air would now appear to be the pole, and to afford a separation between the original and duplicate. Of course the plate should be neither heated nor rubbed with potash or nitric acid, previously to its submersion; and above all, should not remain in an acid solution for a single moment before the galvanic circuit is completed. Sometimes one or more of these circumstances will take place partially, and then a partial adhesion or buttoning will ensue. After any plate has been soldered, it should be allowed to remain in a cold place for at least twenty-four hours, it will then regain its film of air.

(127.) When we are desirous to employ the opposite property, or to cause the new deposit to adhere, we pursue a contrary course; we either heat the metal and plunge it into water, or rub it with a solution of caustic potash, or with nitric acid, and in that state place it in the solution; for then the surface being quite clean, allows the deposit to take place on the metal itself, and not on the pole of air. It will then adhere so firmly, that no mechanical separation can be effected, as some can testify, who, ignorant of these facts, have entrusted valuable copper-plates in acid solutions, and entombed their device in a mass of copper, from which it could never be disinterred. It is not by knowing these principles only, but by putting them into practice, that the electrotyper can attain to any certainty in his operations.

The observations on the infilming of the metals, after having been exposed to the air for a short period, applies to many cases besides the electro-type. The application of heat to the Daguerrotype plate, before it is exposed to the vapour of iodine, is on the same priuciple, and doubtless any of the

other modes which I have described for cleaning the plate, will answer as well.

(128.) The adhesion, or buttoning of one metallic plate to another, must not be confounded with apparent adhesions of the duplicate to the original, arising from the copper growing round the edge, and firmly embracing it. This is to be remedied in a great measure, in the first instance, by coating the edge with a layer of lac varnish or grease, which prevents the deposit taking place at that part. After a considerable lapse of time, the plate increases laterally, and covers the coating.

(129.) The lateral growth of a plate is a property of considerable importance, for if a particle of non-conducting substance be placed upon a metal, it will be covered. In this way, drawings made on copper, with varnishes, may be multiplied. If a non-conducting substance is to be copied, by means of a thin film of conducting substance, a break in the continuity of the latter will not prevent the formation of a perfect plate. For the same reasons, care must be taken that no air or gas-bubbles adhere to the plate, for in like manner they will be infilmed, and leave a little flaw or gap in the duplicate plate. To cast metals upon an air bubble, seems at first too wonderful to be believed, and in former times, would doubtless have subjected the discoverer to destruction, upon the supposition that he was in communication with an evil spirit; but in these latter days, we find that it is even more difficult to prevent than to effect.

CHAPTER II.

ON SUBSTANCES CAPABLE OF RECEIVING THE METALLIC DEPOSIT.

(130.) The voltaic deposit of metal may take place upon any conducting substance, which is capable of acting the part of the negative metal, in the arrangement. The laws which relate to this, are the same which regulate, in a similar manner, the plates of the battery. The deposit may be effected upon most metals, except the earthy and alkaline, and upon any alloy or compound of them. It may likewise take place upon charcoal and plumbago. When the metals are employed, the effect is evident enough, for the arrangement differs in nothing from that of a Daniell's battery.

(131.) Where we desire the duplicate to possess a surface and form exactly like those of the original, it is of the utmost importance that the metal on which deposit is to take place, should not of itself decompose the fluid, because, in that case, the duplicate is sure to be more or less impaired. To illustrate this, zinc, lead, tin, or iron, in sulphate of copper, precipitates the copper immediately from its solution, but the former metals are dissolved, exactly in equivalent proportion with the reduction of the latter. The solution of this metal impairs the surface, and renders the duplicate less perfect. This may be prevented, in a great measure, by taking care that the voltaic current is passing at the moment when the metal is plunged into the fluid; and this mode of proceeding is supposed, by many, entirely to supersede the elective affinity, as it is termed, or the spontaneous action of the metal on the fluid. But I

can decidedly affirm, that a battery of twelve cells will not entirely prevent the solution of the more oxydable, and the reduction of the less oxydable metals.

(132.) The metals which can be employed with advantage to receive a deposit of any other metal, are therefore those which are not acted upon by the particular fluid in which they are immersed; those however, which are but slightly acted upon, may still be employed. Platinum, from its being unaltered by any solution, holds an important place for the reception of every metal; its great value however, must ever be an impediment to its general use.

(133.) Gold is equally valuable with platinum, but is still more expensive; yet when extended to that state in which it exists as gold leaf, it may be applied over the surface of any soft substance, and thus a metallic surface is presented. This mode may be employed with other metals, such as silver or tin; but we have other methods, which render all these modes useless.

(134.) Silver is only reduced by gold and platinum, and therefore may be employed for the reduction of metals, when we require the deposit to be of very pure metal. Silver leaf of a thickness of about one square foot to the ounce, and made of pure metal, is much used by the forgers. The process they adopt is, to place the coin to be copied on a piece of wood, and upon the coin they place a piece of this thin silver. They beat it gently with a wooden mallet, till a perfect impression is taken on the metal, a result soon obtained. They then copy the opposite side of the coin in the same way. The two impressions are then soldered together, and the manufacturer sallies forth and risks his neck for the illicit shilling, which has cost him this labour. The reader will doubtless have no inclination to practise this fraud, and therefore it is unnecessary to enter into the process farther; but it should be borne in mind, that the same means may be employed, with a better intention by the electro metallurgist, to obtain a mould.

(135.) The alloys of lead which are principally employed, are pewter, the fusible metal, and the type metal. The first is an alloy, consisting of about eighty parts of tin, and twenty of lead, but for many purposes, more lead might be added. There are many varieties of this alloy, containing either copper, antimony, or bismuth, but the first I believe will be found to be the best. The fusible metal has been much used by the electro-metallurgist for small casts, but its manipulation is difficult. It should be melted over a lamp, and the surface skimmed perfectly clean. A portion is then to be poured upon any flat surface, and the medal is to be placed upon it with a jerk, and firmly pressed. The metal should be nearly at the point of congealing before the impress is given, or the surface of the cast is apt to exhibit a crystalline appearance. The fusible metal of Sir Isaac Newton, contains lead, bismuth and tin, but mercury is generally added by the instrument makers to render it more easily fusible; the mercury, however, should always be omitted, when the alloy is to be used for taking casts. The composition of the type metal is stated to be about one part of lead, to sixteen of antimony, with a small portion of copper. Considerable practice is required to make casts either in the fusible or type metal, and I am informed that even in type foundries, a man rarely excels in the casting of more than a few letters.

The Italians have a method of taking very perfect moulds with pewter. They take a portion of the melted pewter and place it on a piece of paper; upon this they lay the medal, and under both a piece of carpet; upon the medal they place a log of wood, and then a sharp blow on the wood will ensure the sharpness of the cast. The worth of a cast thus made, is from six pence to half a crown.

An impression may be given to a perfectly clean bright surface of sheet lead, by placing upon it the object to be copied, and then with a steady hand dealing a heavy blow. By this mode even a sealing-wax impression may be copied, although this at first sight would appear hardly credible. By

pressure alone, it would be difficult to obtain the result, which can be given by the blow.

Rolled lead, first scraped, in order to remove any oxide from the surface, and then flattened by running it through a press upon a polished iron plate, will readily take the impression of the most delicate work or engraving. The object to be copied, is simply to be placed upon the lead, and then the two are to be sent once, and once only, through the printing press, as in the ordinary operation for taking a print. This mode is perfect, and answers well for any case. The pressure in rolling is far greater than can be given by direct pressure, though there are instruments, which are used by embossers, capable of exerting great power.

The metal employed for stereotyping, is applicable to the electrotype. A mould in this metal is taken in a particular way from plaster, but it requires certain apparatus which there is no need to describe, as any article can be easily obtained from the foundry.

(136.) Non-conducting substances are of three kinds; substances having no affinity either for the metal or the solution; substances acted upon by the solution; and lastly, substances capable of combining with the metal thrown down. Those of the first class are by far the most valuable, but are not very numerous. The best of these is sealing-wax, a composition of shel-lac, venice turpentine, and colouring matter. Dr. Ure gives, as the proportion in which these are used, four, one, and three. The manufacturers have several varieties, the most expensive of which is the best for making seals. Some of them are extremely hard, as for example, a black wax which is used for filling up the letters in the engraved plates of shop windows, but I do not know how a difference of composition can affect the properties of the wax in this important manner. The use of sealing wax is attended with considerable expense, as good wax cannot be purchased under three and sixpence or four shillings a pound, but it takes impressions of objects of the greatest delicacy with the

utmost accuracy. Every one uses this substance, and sealing is one of those operations in which every one thinks that he excels his neighbour in the manner in which he performs it; but however well satisfied he may be with his skill in the small way, yet the management of large seals is attended with great difficulty and uncertainty. Proof seals are made by engravers, by holding a piece of card over a flame, and rubbing gradually a stick of wax, previonsly softened by heat, upon the heated card, till a snfficiency is obtained, when the coin is to be pressed upon it. Very large seals are made by taking a good sized stick of wax, and holding it in a flame, not only till the point, but even three or four inches of its length are lighted. It is then to be held over a piece of paper or card, when large drops of melted wax will keep falling, and in a short period a considerable quantity will be melted. The flame of the stick is to be blown out, and the fluid mass well stirred round and round, till all the air bubbles are dispersed, and a clear surface of semi-fluid wax is exposed. It is now ready to receive the impression of the object of which we are desirous of obtaining a copy. This is to be laid upon the wax, and pressed with considerable force, and lastly plunged into cold water, so as to cool it suddenly. Much less difficulty attends the use of a metallic die, for that abstracts the heat, and does not adhere.

When we are desirous to obtain an impression in wax, from wood or similar substances, they should be previously brushed over with a little salad oil. In these cases, by plunging the wax into cold water, its surface is apt to sink in places, and thus becomes uneven. Very large seals have been made of sealing wax, by means of placing the medal on the semi-fluid composition and subjecting it to hydrostactic pressure. In this way the late Mr. Bates succeeded in making perfect seals of four or more inches in diameter.

(137.) White wax may be used for taking casts, and can be procured with least expense by buying the waste ends of wax candles, which may be readily melted over a lamp. The

object to be copied is to be very lightly oiled, and enveloped in a piece of paper, which should be tied round the edge with string. By this proceeding we form a kind of rim to the medal. The fluid wax is then to be poured into the cup thus formed, care being taken that no bubbles of air adhere to the medal. It is then suffered to remain not only until it becomes solid, but even quite cold, which will not take place in less time than two or three hours, on account of the wax being a bad conductor of heat. It may then be taken off by gently pulling the wax cast from the medal.

Plaster casts may be even copied in wax, by simply oiling the plaster with a little sweet oil, previously to pouring in the fluid, and thus a perfectly sharp reverse of the plaster will be obtained. A still better method of taking a reverse from plaster, is to let it absorb as much hot water as it will take up without any remaining on the surface. It is then to be enclosed in paper, and melted wax poured upon it whilst it is warm; after which the whole is to be allowed to cool, when the wax will separate from the plaster with the greatest facility. Should the slightest adhesion exist, it shews that the plaster has not absorbed sufficient water, a circumstance which the operator must avoid another time, for with care, the plaster will not be injured in the slightest degree by this proceeding.

(138.) A mixture of equal parts of bees wax and rosin may be employed for taking casts, and may be used in a similar manner to wax. This composition is used a great deal by the Italians, but care must be taken not to use the fused mixture too hot. The composition should be melted, and then allowed to remain till the bubbles have dispersed, and till it becomes nearly as thick as treacle, when it is to be poured over the object, in the same way that white wax is used.

(139.) Of the second kind of non-conducting substances, there are several varieties; as paper, plaster of paris, &c., which are acted upon by the fluid. Paper rapidly absorbs the fluid of the solution, and becomes rough, and therefore it

must be treated with various substances, in order to give it a perfectly uniform surface. It may be brushed over with a little drying oil, such as linseed or nut oil; I give the preference to the former. The oil should be thoroughly boiled, so that it may dry as quickly as possible, after its application to the paper. The substance to which the oil is to be applied, should be clean. It is then to be brushed lightly over with a camel's hair brush till all absorption ceases, and the surface is left shining, owing to the small quantity of oil still remaining on the surface; but great care must be taken that the plaster or paper be just saturated, and no more, as the superfluous oil, by drying on the surface, will fill up the space between the fine lines. The paper must then be left to dry for about twenty-four hours, and if possible be exposed to the sunshine. It is then ready to receive some conducting substance, of which I shall hereafter speak. This mode of treating paper appears, for most purposes, to be superior to every other.

Varnishes may be applied for the same purpose, and as some of them dry more quickly than the oils, their use is attended in some cases with advantage. The principal of these is the white hard, copal, mastic, and carriage varnish. The first dries in a few minutes, and should be applied until a small quantity bears up from the surface. It is best adapted for highly-glazed papers, where the quantity of size prevents the absorption of the more viscid varnishes. The mastic fulfils its purpose very well, but no particular advantages attend its application. The carriage varnish may be sometimes used, but great care must be taken that it does not clog up the fine lines, otherwise it is a most valuable varnish for this purpose, and leaves a very smooth surface. It would be in vain to describe all the modes which may be adopted to render paper non-absorbent and smooth,—it is the principle to which I wish to call particular attention. Sometimes a mixture of bees-wax and rosin previously fused, may be applied, particularly to the absorbent papers. The paper should be held

over a flame so that it does not burn, and the composition rubbed upon the opposite side to that on which we desire to make the copy, till the paper is thoroughly infiltrated, when it will be found not to pass beyond the surface. The paper is hard in a few minutes, and ready for the solution. This is an excellent process, and one which may be frequently adopted. Sometimes rosin itself may be used, but it is apt to be brittle. Other substances may be employed in a similar manner, as balsam of canada, &c.

(140.) The preparation of plaster of paris is of the utmost importance, and the destruction of its absorbent property is to be obtained by means similar to those employed in the preparation of paper. Plaster of paris is sulphate of lime, or gypsum, deprived of its water of crystallization by heat. In this state it has such an affinity for water, and is capable of taking up so much, that when the powder is mixed with water, till it becomes of the consistence of cream, it sets after a few seconds into a hard mass. In the manufacture of plaster casts, we must pay attention to several little niceties, in order to get rid of all the air bubbles. These arise from two causes, either from the adhesion of the air to the plaster, or from the plaster carrying down air with it, when added to the water. The first is to be remedied by using fresh burnt plaster, which is always adopted by the cunning stereotypers, for they state that if it simply stands a fortnight, the casts will not be so good. The workman cannot explain this, but the rationale was well known to Mr. Wyatt, our celebrated sculptor, who told me that he attributed it to the adhesion of the air; and that thus many delicate casts were injured. He places the common plaster in a saucepan over the fire, and heats it, when it heaves from the discharge of the gas, and is then ready for use. Sufficient plaster should be placed in a basin, and water poured upon it till it is completely covered, and all bubbles cease to rise, when it must be thoroughly mixed by rubbing it together. The surface to which it is to be applied, should be slightly brushed over with a very small quantity of salad

oil. A little fluid plaster may then be poured on the cast, and with a hog's-bristle painting brush, thoroughly rubbed into all the fine parts, which will prevent the adhesion of any air bubbles in the plaster which might prevent a perfect impression. Another portion of plaster, sufficient to give the desired thickness is now to be added, and time must be given for the whole to set, when it should be removed from the mould, and gently heated over a fire to drive off excess of moisture. It is then found to be exceedingly hard, and ready to receive substances to destroy its absorption.

(141.) The best mode of treating plaster casts is to place them in a flat dish with either bees wax alone, or with a mixture of equal parts of bees wax and rosin previously fused. The wax and rosin should not exceed half the height of the cast, and the heat employed should be sufficient to render the composition perfectly fluid. After a short time, the whole is to be raised to a considerable temperature, and then some of the fluid may be brushed over the hot plaster, which will absorb it, and upon waiting a little while the whole of the plaster will be filled with the composition; the plaster is then to be removed and drained, after which no wax will be found to remain on its surface, but its texture will be completely filled, and thus a beautiful non-absorbent and smooth surface is procured. This is an excellent method of treating plaster casts, and is attended with but moderate trouble. The more rosin is contained in the above composition, the higher will be the heat required for its perfect fusion, and although rosin will answer by itself, yet it cannot be made to penetrate beyond a very little distance into the texture of the plaster, though a clean, hard, non-absorbent surface can by this means be produced. The solution of rosin in oil of turpentine may be used, but it is difficult to drive off all the turpentine. A mixture of rosin and grease may also be used. White wax, such as that obtained from wax candles, answers very

well to prevent the absorption of plaster, and is very easy to apply.

Common tallow succeeds admirably well in filling plaster. It is readily melted, and from its fluidity passes into the numerous pores of its texture. It is as well thoroughly to boil the cast in the tallow, and then drain off the superfluity, and afterwards leave it in a cool place to harden. The hardest tallow should be selected, but good candles answer every purpose.

Stearine is nothing more than common tallow, with the fine fluid parts or elaine removed by pressure; it answers perfectly to fill plaster. The melted stearine is to be employed in a manner similar to tallow.

Spermaceti also renders plaster non-absorbent, and is to be applied in the same way as the tallow. Spermaceti, as sold for candles, answers the purpose well.

The application of boiled linseed oil is another mode which may be practised. It should be applied to the cast until a very minute quantity remains unabsorbed on the surface; it is then to be dried, and this is best accomplished by free exposure to sunshine. The mere hardening of the exterior film does not indicate a sufficient dryness for the object to be placed in the solution; for it is necessary that the oil should be somewhat dry throughout. If the object be placed in the solution, previously to its being dry, the oil will separate from the plaster, and the solution will act upon the cast, and both cast and solution will be materially impaired, if not utterly destroyed. Plaster requires a large quantity of oil for its saturation, perhaps as much as half of its bulk. The casts should not be over dried when the oil is applied, as the oil does not then so readily harden.

The same observations which apply to varnishes, balsam of canada, venice turpentine, &c., with respect to their application to paper, apply also to plaster articles. Of varnishes, the mastic, and white hard are the best, but the formerly described methods are superior to those in which any of the

varnishes are used. Experiments have been tried upon every other substance likely to be useful, but these it is needless to describe.

I am tempted to give a table of the substances which may be applied to plaster, as a summary of the results of my experiments, taking into consideration their relative efficiency as well as cheapness :—

Tallow	Nut oil
Stearine	Solution of rosin in turpentine
Spermaceti	Balsam of canada
White wax	Mastic varnish
Bees wax and rosin	White hard varnish
Rosin	Lac varnish, &c.
Linseed oil	

(142.) The third class of substances, which comprises those which are acted upon by the metal reduced from the fluid, are few in number; yet unfortunately this class contains one substance which takes finer casts than any other, and that is sulphur. The newly precipitated metal no sooner comes in contact with the sulphur than it combines with it, forming a sulphuret, and the cast swelling enormously, is quite disintegrated. The only mode of remedying this is to coat the sulphur mould with a varnish, such as, for instance, white hard and mastic, of which a very thin layer should be applied; however, the sulphur casts have not answered well under any treatment, and as we have so many other modes of taking casts, there appears no inducement to follow the subject farther.

(143.) Non-conducting substances may be copied or multiplied by depositing a thin film of any conducting substance upon this; and gold, silver, bronze, or copper powder, might be employed for this purpose.

There is another process by which non-conducting substances, such as animal matter, vegetables or minerals, may be coated with the finely divided metal. The object is to be brushed over with a small quantity of the solution of any salt

of gold, silver or platinum, and in that state is to be exposed to the vapour of phosphorus, from the evaporation of either the alcoholic or etherial solution, when immediately a deposit of finely divided metal will take place on the surface. It has been supposed that this is a phosphuret of the metal, but if a little piece of phosphorus be placed in a solution of gold, silver, platinum, or copper, the phenomena will be explained, as the respective metals will coat the phosphorus. The deposit of copper is particularly beautiful.

The substance to be copied may be also brushed over with a solution of any of the metals last mentioned, and exposed either to sunshine or to heat, when reduction will take place; but the process is tedious, aud is therefore very rarely employed. Any other mode by which the metals may be reduced, would suffice; as for instance, their reduction by proto-sulphate of iron, or hydrogen gas.

Gilding, silvering, or coppering objects by means of their respective leaves may be employed; yet all these modes are imperfect, and we have no need of any metallic covering whatever, as other means answer the purpose better, and are even more simple and cheaper.

(144.) The best method of giving a non-conducting substance a thin conducting layer, is the application of carbon, either charcoal or powdered black lead. It is only necessary to brush these substances over the object till the thinnest film is obtained, as that will be amply sufficient for the purpose for which it is wanted. The black lead is the best on account of its peculiarly unctious nature, which enables its application to be made with the greatest ease, either by a camel's hair, or hog's bristle brush, according to the nature of the substance to be covered; care must however be taken, that the interstices between the fine lines are not blocked up, as this would of course render the duplicate imperfect. Occasionally there is some difficulty to make a thin film adhere to the surface, but if it be an object where perfect sharpness

is not indispensable, a small quantity of varnish may be applied, which is suitable to earthenware. Sometimes a little spirit of wine may be used, when a cast is capable of being acted upon by that fluid, as sealing wax, but great care must be taken not to render the surface rough. Upon many substances, the black lead may be made to adhere by simply breathing upon the object. In whatever manner we cause its adhesion, it is important always to bear in mind, that it is of more consequence that a smooth polished surface of black lead be exposed, then a thick rougher coating.

The different opinions which are entertained, as to the applicability of black lead for this purpose, are owing entirely to the fact, that great differences exist between one sample and another, of that article; for if it be not really carbon, it is absolutely a non-conductor, and I have found a number of pieces totally inactive, while others were most excellent conductors. The action or inaction of different pieces, before grinding, is not all dependent on the hardness, for I possessed a piece of that variety, which is called rock by the pencil makers, which completely annihilated the teeth of three of my saws, by which I attempted to cut it. I then sent it, for the purpose of having it sawed, to a celebrated mechanic, and he succeeded no better than myself; in fact, nothing but a diamond would have made any impression upon it, and yet it was one of the best pieces for voltaic purposes which I ever possessed. Sometimes, on the contrary, hard pieces are of no value, whilst soft pieces are excellently adapted. There is no method but direct experiment, by which the conducting quality of any particular sample of black lead can be ascertained. There are not two shops where it can be bought alike, so much is either naturally bad, adulterated, or ill prepared. Perhaps the best test of good black lead, is to take a pinch between the finger and thumb, and press it; when, if good, it will cake together and adhere. If charcoal be employed, it should be well burnt, and in the finest possible

state of division. The prepared charcoal of the shops exists in the state of an impalpable powder, but it is difficult to apply it.

(145.) Of all these various methods, none is, in my opinion, at all comparable to good black lead. The thinness of the coating is such, that it is not snfficient, of itself, to carry the voltaic current (for a layer so thin as only to be visible by reflected light, is sufficient) but this thin layer so favours the extension of the copper laterally, that the whole surface speedily becomes coated. It is very interesting to trace the layer of copper extending itself over any object. For this purpose, a piece of black sealing wax, coated with black lead, answers best, as the difference of colour renders its mode of precipitation very evident. It will be seen that the copper grows perhaps from some point of the wire, on to the black lead, and gradually extends itself laterally till the whole is infilmed by the metal.

CHAPTER III.

ON THE LAWS REGULATING THE REDUCTION OF THE METALS.

Metals capable of being reduced by the voltaic fluid, 146. States in which they exist, 146—148. Law for the reduction of the metals as a black powder, 148. Law for the reduction of the metals in crystals, 149. Law for the reduction of the metals in a reguline state, 150. Causes of the varieties in the reduction, 150. Mode of producing them, 153—159. Mode of obtaining the black powder, 159. The crystalline state, 160. The reguline state, 161. The same results obtainable by the single cell apparatus, 165. Time required for the deposition of the metals, 167.

(146.) All the metals can be reduced by the galvanic current, or by the secondary action of the hydrogen arising from the decomposition of water; only a few, however, can be advantageously reduced in this way, for the purposes of the arts.

These are gold, silver, platinum, palladium and copper. The other metals which I have reduced in a reguline state, or in the state in which we usually employ them (and not as a black powder, or as crystals) are iron, bismuth, zinc, lead, tin, antimony, nickel, and manganese. Most of these can be used as a solid coating, so as to take the form of any conducting or non-conducting object, or as a thin film to serve as a protection or ornament to the body on which it is deposited. These two purposes are so different, that each will merit a separate book in this treatise; but here, the peculiar management of each metal separately, will be entered into.

(147.) The laws which regulate the deposit of every metal appear to be the same, and although very simple, they have cost me much labour for their development. The properties of which I have here to speak are strictly those which relate to the quality of the metal, which is materially influenced by various circumstances. The reduced metal may be precipitated in three different ways; as a black powder, as a reguline metal, (or in other words a metal having the properties of ductility and malleability) and lastly, it may be thrown down in a crystalline form. Between these there are indeed other intermediate states, or mixtures of two different states, but of which we need not here take any notice.

(148.) Law 1.—The metals are invariably thrown down as a black powder, when the current of electricity is so strong in relation to the strength of the solution, that hydrogen is violently evolved from the negative plate of the decomposition cell. The term violently may seem to require some explanation, for the metal will be thrown down as a spongy powder, even when but few bubbles are given off in the half minute.

(149.) Law II.—Every metal is thrown down in a crystalline state, when there is no evolution of gas at all from the negative plate, or no tendency to it. When I speak of no tendency to the evolution of the hydrogen, I mean, that either electricity of a much greater tension must pass, or the solu-

tion must be rendered of more easy decomposition, before gas would be evolved. The crystals may be small or large according to circumstances to be noticed hereafter.

150. Law III.—To throw down the metals in the reguline state, we must use a quantity of electricity just sufficient to cause the minutest quantity of gas to appear at the negative plate; in other words, the quantity of electricity passing should cause a great tendency to the evolution of the hydrogen, if it be not actually slightly apparent at the negative metal. To say that hydrogen should be given off slightly from the negative plate, may lead to error unless duly qualified, for it is only meant that a few bubbles should adhere to the negative plate, after the action has been continued for some hours, for there should be no farther evolution of gas. In fact, the reguline state is obtained in the greatest perfection when hydrogen is just at the point of evolution, but yet none is really given off from the negative metal.

151. The causes of these variations are difficult to conceive, but perhaps we may venture a theoretical explanation. We have seen in a former part of the work, that the metals may be reduced in two ways. First, Professor Daniell has shown that the metallic salt yields its base frequently, as the direct result of the passage of the galvanic fluid. Secondly, it has been shown, that the metal may be reduced, as the secondary result, from the agency of the hydrogen, which is derived from the decomposition of water. Now it appears to me possible, that in every case where we require the newly deposited metal in its most flexible form, it is to be obtained principally, or even entirely, from the secondary decomposition, or that by means of the hydrogen. A superabundance causes it to go down as a black powder, but a more moderate quantity ensures the deposition of the flexible metal, or in the state in which it is required for the arts. It is by no means improbable that this flexible state is nothing but an agglomeration of the fine powder, in the same way that rolled platinum is an agglomeration of spongy platinum. I would

venture still further to suggest, that the crystallized state may arise from the decomposition of the salt, by the direct action of the electric current.

(152.) Dismissing theories, however, we must remember these facts; that the electric power in any solution, when barely sufficient for the production of hydrogen, causes the reduction of the metal in a malleable and ductile state; that the electric power, when not nearly sufficient to cause the appearance of the gas, throws down the metal in crystals; and lastly, that the black pulverised deposit is produced when there is evolution of the gas.

(153.) A very brief examination of our laws will show that the two properties of galvanic batteries must operate in an important manner in producing these results, and accordingly we find that some circumstances are produced by quantity, others by intensity. The regulation of intensity is, perhaps, of the greatest importance; for on the one hand, economy requires as few cells as possible, and on the other hand, other circumstances require more. Whenever it is possible, the fluid to be decomposed should act on the positive pole of the fluid. Thus, in the decomposition of salts of silver, iron, lead, tin, and copper, we use in the decomposition apparatus, positive poles of these respective metals. This enables us to conduct our precipitations with a single cell, which, with my battery, enables us to obtain any given amount of work with the smallest possible cost. During the decomposition, the metals mentioned above are dissolved precisely to the same amount as that to which the new deposit is obtained. The solution is in the same way, always of the same strength.

(154.) The degree of action of the fluid on the positive poles, or rather of the oxygen and acid transferred to the positive pole, varies with every salt of the same metal. To regulate the action equally in different cases, acids, either of more or less oxygenating power, or in greater or less quantity, are added to the metallic solution to be decomposed. An

increase or decrease of the temperature, influences, materially, the intensity required for different salts, because the current passes at a higher temperature with more facility, as the action on the positive pole is more energetic. These minutiæ have hereafter to be fully discussed; but here I wish to point out, that when possible, only one cell of the battery is to be used, and that where this is rather deficient in intensity, a compensation can be obtained by adding acids to the metallic solution, of more or less affinity for the positive pole, according as that may be required.

(155.) For those cases where we use a positive pole or anode made of platinum, we are compelled to obtain increased intensity by employing a more extensive series of batteries. In these cases, we must use as many cells as will decompose water; three or four in general will be amply sufficient. Beyond the mere capability of decomposing water, I cannot perceive that increment or decrease of the intensity, is of material importance, and the regulation of the quantity must then be made the subject of attention.

(156.) The quantity of electricity passing in any fluid will depend, cæteris paribus, upon the distance between the electrodes, the extent of surface they expose to the fluid, or their relative size one to another. These properties have been already described, when treating of galvanic batteries in general, and therefore do not require farther description in this place. However, a different quantity of electricity is required for every variation in the strength of the solution; as any increase of the metallic salt requires a corresponding increase in the quantity of electricity; and the converse is equally true. The effect, however, of an increase of quantity in any solution where there is not intensity enough to produce much hydrogen, would be only to increase the amount of crystallization, or the size of the crystals.

(157.) The quantity of electricity passing in a solution, curiously influences the state of the crystals, for there are two varieties of this deposit; one of which arises from a deficiency

of quantity, in relation to the strength of the solution, and in this state the new plate of metal is like an aggregation of sand, in fact, like common sandstone, the particles having no more cohesion or consistence. In this state, the plate of metal is in the utmost state of brittleness, and this, we must recollect, is produced by too small a quantity of electricity in a strong metallic solution. The second variety of the crystalline state of metals, arises from a large quantity of electricity, in relation to the size of the plate; thus, by using a very large positive pole, connected with a very large battery of feeble intensity, and by employing, at the same time, a strong solution, large crystals, possessing the utmost degree of hardness, will be thrown down.

(158.) To carry into effect these general laws as we may have occasion for them, let us recapitulate the circumstances which may affect them. First we have the size of the battery, secondly we have the strength of the solution, thirdly we have the arrangement of the poles in the decomposition cell, and finally we have the temperature of the solution to be decomposed.

(159.) In any given solution we may increase the disengagement of the hydrogen to cause a black deposit, by increasing the intensity and quantity of the battery, by a series, by diminishing the size of the negative pole, and enlarging the positive electrode, by approximating the electrodes or poles, and lastly, by increasing the heat. All these conjointly, or any of them separately, will favour the increase of electricity, as they will increase the quantity of hydrogen evolved.

For any given size of the negative plate we can obtain a black deposit, by increasing the intensity and quantity of the battery; by increasing the positive electrode; by diminishing the quantity of metallic salt in the solution and adding to its acid, and by approximating the poles.

With any given battery (provided it will decompose water) we can obtain a black deposit, by diminishing the size of the negative pole, by increasing the size of the positive, by

approximating them, and by rendering the metallic solution very weak with dilute acid.

(160.) To obtain a crystalline deposit with any given solution, we increase the quantity of electricity, but diminish the intensity derived from the battery. We increase the size of the positive pole, diminish the negative, and we approximate them.

With any given negative plate we can obtain a crystalline deposit, by diminishing the intensity of the battery, enlarging its size, saturating the solution with the salt, and taking care that it is not acid. The positive plate may be enlarged, and approximated to the negative.

With any given battery we can obtain a crystalline deposit, by strengthening the saline solution, and not acidulating it, by diminishing the negative electrode, increasing the positive, and approximating them.

(161.) To obtain the metal in the reguline state, however, is our great object, and to obtain the exact point of evolution of the hydrogen, is important and difficult. With any given solution, if we find the hydrogen too abundant, we may either increase the negative pole, or diminish the positive, which will be sufficient for many cases. But in some cases we are desirous of having the electrodes of the same size, and then we diminish the size of the plates of the battery, or the strength of its charge; for instance, I sometimes use my battery charged with water, and a faint trace of acid. Again, in other cases we are desirous to increase the rapidity of the process, and then the evolution of the hydrogen will be diminished, by increasing the quantity of metallic salt in solution, which will answer every purpose. Variation in the distance between the poles will be found sufficient, in many cases, to regulate the evolution of the hydrogen. The converse of all these properties is equally applicable to those cases where the hydrogen is deficient. By regulating the strength of the metallic solution, and adding more or less dilute acid, the evolution of the hydrogen, in any battery (provided it be sufficiently intense to decompose water) will be perfectly under control.

(162.) Thus, with any amount of salts in solution, with any sized negative plate, with any sized battery, and at all temperatures, we can obtain the reduction of any metal in the state we please. It is true that this excessive refinement has hardly been carried to every metal, yet the principles have been so far accurately demonstrated with such a number of them, as to leave no doubt of their general truth and value.

(163.) A pretty experiment was devised to show these laws in a more simple and certain way. Into a strong solution of sulphate of copper, contained in a tall vessel, dilute sulphuric acid, with a little sulphate of copper, was poured gently upon the top; this, being lighter, swam on the top, whilst the saturated solution was at the bottom; a long wire, as a negative metal, was passed to the bottom of the vessel. A circuit was then completed. After a short period the wire was removed, when the bottom was found coated with thick, hard, copper crystals. About the middle it was more flexible, and at the upper part the spongy mass was found. The liquid was then stirred up, in order that an intimate mixture might take place, and another wire subjected to the same experiment, when this was universally coated with copper of uniform texture.

(164.) In detailing the above laws, the battery has been spoken of, because we can, by its means, regulate most exactly the quantity and intensity of the current. The same principles apply to the cases in which the metal on which the reduction is to take place, is made the negative plate, to a piece of zinc, enclosed in a porous tube, but we cannot adapt this with that nicety which the battery admits.

(165.) The quantity of electricity in a single cell apparatus, may be increased by enlarging the zinc plate, by approximating it to the negative, by diminishing, as much as possible, any resistance offered, by the use of the diaphragms, and by adding to the acid of the solution which acts upon the zinc. The quantity of electricity may, in like manner, be diminished, by adopting an opposite course of proceeding. In the use of the single cell apparatus, as in that of the battery, the strength of

the metallic solution to be decomposed, will materially influence the quantity of electricity required for its reduction. The neutrality of the solution, the acidity, or the nature of acidity, will operate in a similar manner. The different conditions have been quite sufficiently adverted to, when speaking of the effects of those circumstances, in the use of the battery. The above facts alone are sufficient to make forcibly apparent the imperfection of the single cell apparatus, and the superiority of the process by the battery.

(166.) There are certain peculiarities appertaining to each metal, and even to each salt of the same metal. Each of these demand somewhat different management, depending upon the circumstances under which the reduction of the metal takes place. The variation in the modes of operating will be entered into in the next chapter.

(167.) And now let us consider the influence which time exerts over these processes. Is it necessary, as all authors have asserted, that the voltaic precipitation should go on slowly? The fundamental laws which regulate the precipitation of metals exclaim at once, by no means. For if the electric power be regulated to the strength of the solution, precipitation may take place at a rapid rate. In fact, we shall hereafter show that the reduction of the metals may be more speedily effected than at first sight appears possible, because the deposition is amenable to the same laws whether it takes place slowly or rapidly.

CHAPTER IV.

(168.) We have now to treat of the metals which may be reduced from their salts by the galvanic current, and of the peculiar management which each salt requires.

The salts of all the noble metals are easily decomposed, and the hydrogen has a great tendency to be evolved during their decomposition; on account of which, particular care must attend the reduction of them all. Gold is generally dissolved in nitro-muriatic acid, forming a chloride or muriate of that metal. This is a very soluble salt, and an excellent conductor. From the quantity of electricity which passes, during its decomposition, the hydrogen appears to have a great tendency to be evolved. The strength of the solution used, may be from the palest in colour, to the most concentrated, taking care to follow the laws already laid down; for if no hydrogen be evolved at the negative pole, the gold will not be precipitated in the least degree, as a black powder; and in that way I have actually worked a solution of gold till it became absolutely colourless. The surface of the negative metal on which it is thrown down, should be bright, and a very small quantity of electricity should pass, no matter what its intensity, in proportion to the strength of the metallic solution. The positive pole should be small, and by varying the size of this, we may regulate, to the greatest nicety, the quantity of electricity passing. By attending to these rules, no difficulty will be found in throwing down gold from the strongest solutions. During the decom-

position of this salt, chlorine is freely evolved; and this is apt to attack, slightly, the positive pole, though it will not operate materially upon it. The positive pole should either be of fine platinum or gold wire, and it will be frequently sufficient to place the smallest part of the end in the solution.

The negative pole may be of gold itself, carbon, or platinum, as all these are applicable to the reception of the gold, being unaffected by its solution. Even metals which act upon the solution may be employed, care only being taken that these are not allowed, for a single moment, to be in contact with the fluid, without the galvanic circuit being completed. At first the solution should be very weak, but after a gold surface has been obtained, it may be rendered stronger by the addition of more concentrated solution. The larger the negative plate, the more readily will the reduction be effected; for then the positive pole need not be so extremely small.

There are other soluble salts of gold, as the solution of its oxide in potassa and soda, or their carbonates, and the bromide of gold; but the nitro-muriate will be found amply to suffice for all these purposes. The alkaline solution of gold is less readily decomposed than the nitro-muriate, and for that reason is perhaps preferable; yet the nitro-muriate, with care, will answer every purpose.

(169.) Platinum may exist in solution, as a chloride, muriate, or sulphate. The circumstances which affect the reduction of gold, affect also that of platinum; and the observations already applied to the former, are also applicable to the latter, therefore it is needless here to repeat them. The nitro-muriate of platinum is a ready conductor, and requires but a very small platinum wire for the positive pole. The colour of the platinum thus reduced, is somewhat that of bright steel, forming a strong contrast to the absolute black powder, in which state it is employed for my battery.

(170.) Palladium is soluble in nitric acid, containing a trace of muriatic, and the circumstances to be attended to for its reduction, are the same as those for the preceding metals.

(171.) In the reduction of all these metals, a compound battery, with a positive pole of platinum in the decomposition cell, is to be used; and the size of this will influence the quantity of electricity. (fig. 7.)

The single cell apparatus might be used for the reduction of these metals, but it is very ill adapted, on account of its being so unmanageable. It should be so constructed as to admit the passage of very little electricity, and I have found the glass tube, with a capillary bore, the form best adapted for the inner vessel (113).

(172.) Silver, on account of its universal importance, demands our most serious attention. The nitrate, sulphate, acetate, hypo-sulphite, and ammoniuret, must be separately considered.

As a solution, from which the silver is to be reduced, the nitrate is for many purposes the most unfavourable of all, and when this salt is used, the hydrogen has a great tendency to be evolved from it, and therefore a relatively feeble current must be employed. The decomposition cell may contain a positive pole of platinum, or even of silver, as the latter will, by being dissolved, always maintain the same state of saturation of the fluid. When a positive pole of silver is employed, there is a risk of materially increasing the quantity of electricity, and therefore only a silver wire should be employed; and then the distance which the operator places them in the fluid, will accurately regulate the amount of current. The negative pole to be placed in this solution, for the purpose of receiving the precitated metal, may consist of either gold, platinum, charcoal, or silver; but the other metals are not at all fit for the purpose, owing to the energy with which they decompose the solution. The strength of the solution of this salt may be from ten to four hundred and twenty grains to the ounce of water, taking care that the electricity is regulated in its quantity, according to the strength of the solution, in the manner already directed.

(173.) The next solution of silver is the sulphate, a very

sparingly soluble salt, but nevertheless, a very valuable one from which to reduce the metal, as it is well adapted to those metals which have a stronger affinity for oxygen than silver. From this solution, by using a feeble current of electricity, silver may be precipitated on to copper. We must use all our endeavours to prevent the evolution of the gas in these cases, and the use of whiting appears to accomplish this object. It is to be rubbed over the object, previously to its insertion in the fluid, and also several times during the continuance of the process; the success of which seems to depend, in a great measure, on the frequent application of the whiting to the whole surface, in order to remove any of the dust of silver which may form.

(174.) The acetate of silver is also a sparingly soluble salt, and well adapted for our purpose. Still, with this salt care must be taken to regulate the quantity of electricity. Upon the whole, these two last mentioned salts are the best adapted for solutions, from which to reduce the metallic silver.

(175.) The hypo-sulphite of silver may be readily made, by adding any hypo-sulphite, such as that of potass, to the nitrate, chloride, or any other salt of this metal. There appears to be a strong attraction between silver and this acid, as the hypo-sulphite decomposes the most insoluble salts of silver. The hypo-sulphites of the alkalies may be prepared, by adding sulphurous acid to their sulphurets; as for instance, to the sulphuret of potassium or sodium. This salt of silver is pretty soluble, and will bear a larger quantity of electricity for its decomposition, than the nitrate.

(176.) The ammonio nitrate, and ammonio chloride of silver are very soluble, but do not offer any particular advantages for the purposes of metallic precipitation. Great care is required in the use of these salts, for if the solution, by being kept for some time, be allowed to evaporate, so as to leave dried portions adhering to the sides of the vessel, it can no longer be even touched with safety; for a fulminating salt is thus formed, which if merely touched with the finger, in order

to remove it from the sides of the vessel, will explode with mischievous and awful violence. I take particular notice of this fact, as I nearly lost my right eye in learning it. These salts are good conductors, and their solutions may be used of any strength. It should invariably be alkaline, from excess of ammonia. A negative pole suitable for the reception of the silver, may be made of platinum, gold, palladium, carbon, or silver itself, all of which are unaffected by the solution, and thus whenever we desire a duplicate of silver, the original should always consist of those metals.

The spongy mass can be obtained from any of these salts, with the utmost readiness, by increasing the quantity of electricity.

(177.) Nickel does not demand much attention. It may be reduced from its nitric solution by using a feeble current. Being a noble metal, as well as a cheap one, it may be very valuable for coating copper and other metals. With this substance, as with every other, we must take care that the hydrogen is not evolved from the negative metal, though at the same time, it should not be far below the point of evolution.

(178.) Although the management of the last described metals be extremely interesting, from the novelty, yet perhaps no metal is more important than copper, for the purposes of reduction. Its reduction may take place from several of its salts, of which the sulphate, muriate, nitrate, and acetate, are the most worthy of attention. The sulphate is most commonly used, because it is the cheapest. It deposits thirty-two grains of pure metallic copper, for every hundred and twenty-five grains of the sulphate, decomposed by the voltaic current, and thirty-four grains of zinc are dissolved, for every thirty-two grains of copper, which are reduced. It is a salt of rather difficult decomposition, and offers considerable resistance to the passage of the electric current. Its conducting power, and therefore its facility of decomposition, may be increased by adding acid to the solution, which may be either dilute sulphuric, or dilute nitric acid. A solution, made by dissolving

one pound of the salt in four pounds of water, and by afterwards adding from one third to one half of its bulk of dilute sulphuric acid, is best adapted for many purposes. The dilute acid should consist of one part sulphuric acid to eight of water, well mixed together. This solution answers extremely well, when we have to cover non-conducting substances, to which a metallic or black lead covering has been given; because the hydrogen, with a sufficient battery, has not such tendency to be evolved.

A variation may be made in this fluid, by employing rather less dilute sulphuric acid, and at the same time adding a little nitric acid, by which the conducting power of the solution is naturally increased. The nitric acid attacks the positive pole, so that the metallic solution is apt to become stronger. When this takes place, the solution muct be diluted. The positive pole is more apt to be attacked after the action has continued some little time, for nitric acid is formed, which assists the solution. In both these cases, the reduction takes place with considerable rapidity. The effect of the acids is to diminish the resistance offered to the passage of the electric current, which is virtually equivalent to increasing the intensity; and we find that the quality of the copper obtained by either of these methods is the same, being soft, flexible, malleable, and ductile, but not very elastic. To obtain these qualities in the most eminent degree, the hydrogen should be so regulated to the strength of the solution, that after the plate has been for some hours in the solution, a few bubbles shall be seen to adhere. We generally require the copper to be somewhat harder, and more elastic than this; to accomplish which, we slightly increase the strength of the solution.

The acid solution must not be employed, when the negative plate, or mould to be copied, consists of a more oxydable metal than copper; for the acid would act upon it, and perhaps even entirely dissolve it. In this case, a neutral solution must be used. If in these cases, the copper is required to possess the qualities which I have before described, a series of two, three, four, or more batteries must be used, by which

means intensity is obtained, and the tendency to the evolution of the gas is increased. The cost would be at the same time, double, treble, or quadruple, of that attending the application of one battery. A flexible state can be also obtained by using a dilute neutral solution, with a single battery, or even by employing a stronger solution kept at an elevated temperature.

We can obtain the copper of the utmost possible hardness, though slightly brittle, if we are desirous of employing it in that state, by adopting a somewhat different arrangement; we employ a saturated solution of sulphate of copper, without any acid, a very large positive pole, and we use a cell of such size, that a considerable quantity of electricity is generated. In this case the copper will be found extremely hard, and somewhat crystalline in its appearance. This state may be termed the greater crystalline, and the brittleness depends upon the crystals which form its structure, as a mechanical dissection will show; for if a piece of this copper be broken, a slight adhesion only will exist between the different particles of the copper. When we throw down the copper, however, in this state, it is apt sometimes to play curious freaks; for the reduced metal, appearing to be abundant, passes to the back of the plate, causing nearly as much deposit behind as before. Sometimes it will pass to the corner, producing efflorescences apparently from a similar cause.

179.) From the preceding statement it is apparent, that it is quite a vulgar error to suppose that the brittleness or flexibility, the hardness or softness of the copper, depends alone upon the greater or less quantity of electricity passing, or in other words, upon the rapidity of the process, for a plate may be a fortnight in its precipitation, and yet so brittle as to break with the slightest touch; and again, when the process has been performed in two days, the metal has exhibited great flexibility. We may reverse these results by altering the circumstances; thus, a plate may be a fortnight in the making, and by using a weak solution, and a slight current,

be yet flexible; or it may be made in two days, and still brittle, by using too great a quantity in a very strong solution. The flexibility depends upon the quantity of electricity being suited to the facility with which the reduction of the metal from any solution is effected, and upon the quantity of salt contained in the solution; thus, with a neutral solution of sulphate of copper alone, in order to obtain a flexible and soft plate, a small quantity of electricity must be employed, and that with a weak solution, if it is attached to only one cell of the battery; a stronger solution, with a series of batteries, may be used with the same result. If the solution be very acid, a more considerable quantity of electricity of a single cell may be employed with the same result, agreeably to the laws regulating the precipation.

Extreme brittleness may be produced by using a deficient quantity of electricity in a strong solution. In fact, the plate looks as if it were nothing but an agglomeration of sand. This state may be called the lesser crystalline.

The copper may be always thrown down as a black powder, by employing a very powerful battery, or by the other general methods stated in the description of the laws.

(179.) The nitrate of copper is a salt far more easily decomposed than the sulphate. It is an expensive salt, out of all proportion to the trouble of preparing it but in the form of apparatus, where the solution is kept at the same strength, by the aid of a copper positive plate; the first expense is the only one incurred, and thus it becomes a question, whether for general purposes, it be not better to employ the solution of nitrate of copper. The electro-metallurgist may readily prepare it for himself by dissolving metallic copper in nitric acid. The operator must be careful not to expose himself to the nitrous fumes which are then generated, as by inhaling them, the pulse would be lowered, and other disagreeable consequences produced. It may be acidulated with nitric acid, which will increase its conducting power materially, so much that scarcely any impediment will be offered to the current of

a single piece, when a copper positive pole is employed. The hydrogen here has a tendency to be evolved, because but little impediment is afforded to the passage of the electric current. The copper from this solution is excellent, and the rapidity of its deposition exceeds that obtained by the use of all other salts of this metal, because it will bear the solution to be stronger, and still offer some resistance. When this solution is employed, a pound of the salt may be dissolved in a pint and a half of water, and acidulated with half an ounce of strong nitric acid. From a saturated and acidulated solution of this salt, we can obtain a copper plate in the most rapid manner possible. The positive copper pole should be of the same size as that of the negative plate, and the two poles should be placed within half an inch of each other. A series of from four to six batteries must be employed at ordinary temperatures, though at high temperatures less would suffice. A plate of copper should never be made in this way, unless it is wanted in a great hurry, for although the copper is the same in quality, or even slightly superior to that obtained by a single cell, yet the expense attending its precipitation is greater.

(180.) The muriate of copper may be employed, but I do not know that any advantage attends its application. It is not so readily decomposed as the nitrate, but more readily than the sulphate. There are many other salts of copper, but for general purposes they do not offer any interest to the electro-metallurgist. Other salts may be used, as the ammoniuret, acetate, and hypo-sulphite; these salts offer no advantage, when copper or any other metal of less affinity for oxygen, is used for the negative plate; yet, with metals having a greater affinity for oxygen, they may be employed with advantage, for it is important that the negative metal of itself should exert no action upon the saline solution, otherwise the duplicate will be impaired.

(181.) Acetate of copper is formed by digesting common verdigris in acetic acid, and evaporating the product till crystals are obtained. It is a salt difficult to decompose, requiring

the intensity of several cells. The only advantage of its application, is the property which it possesses of not being decomposed by iron, whilst it is neutral.

(182.) The compounds which ammonia forms with the salts of copper, are the ammoniuret of the oxide, the ammonio nitrate, and ammonio sulphate of that metal; the reduction of the metal from these, is attended with difficulties, and it is requisite that the solution be alkaline from the presence of free ammonia. Iron and steel do not spontaneously decompose the compounds, but I am afraid that the only benefit attending their application will not compensate for the trouble and difficulty attending on this process. Both the last salts require a series of batteries to effect their decomposition.

As a summary of the modes of proceeding with various solutions of different strengths, it is to be observed, that the more readily any particular salt can be decomposed, the stronger may be the solution; the more difficult of decomposition, the weaker. A more concentrated solution of a salt requires more intensity and quantity than a weak solution, whilst a weaker solution may have the current of a single battery passed through it. These comprise the whole of the practical secrets for regulating the quality of the copper, and they have materially assisted in the discovery of the general laws which have been already laid down, for in every case the hydrogen is near its evolution when the texture of the copper is at its utmost degree of tenacity.

(183.) It has been mentioned, that rolled copper may be used as the positive plate of the decomposition cell, as, during the action of the battery, it is dissolved to an amount equal to that reduced at the negative plate. It is curious to notice how regularly the plate is thinned, until the whole is removed; but during this process, a considerable quantity of black matter is left, apparently charcoal, arising from impurities in the manufacture of the copper. If an electrotype plate be made the positive pole of the apparatus, no remains will be left, but every particle will be dissolved,

"And leave not a wrack behind."

The piece of copper from the positive pole of the battery may be partially dissolved by coating the rest with any varnish or substance which can resist the action of the fluid, a property of which hereafter we shall have more particularly to speak.

(184.) The negative pole may consist of plumbago, charcoal, gold, silver, platinum, palladium, nickel, and copper itself, for all these are suitable for the reception of copper. All other metals are more or less acted upon by the solution, though lead and its alloys may be used with the sulphate of copper, especially if it be diluted. Tin is much inferior to lead, for the reception of this metal, being more readily acted upon.

(185.) The copper thus reduced, assumes the form and appearance of the cast on which it is deposited. If the surface of the original be polished, the duplicate will be so likewise, and the colour will, in many cases be slightly influenced, especially where copper has been used as the original. The surface is not so brilliant, where lead, tin, and such metals are employed, but when black lead is applied on smooth surfaces, as sealing wax or white wax, the surface of the duplicates will be perfectly bright.

(186.) For copies of medals, a copper surface is not desirable, bronze having a much better appearance, and this may be communicated in various ways. The one most generally adopted is the following. The medal is to be covered over with oxyde of iron, and placed in a muffle, and in this state, exposed to heat; when removed from the fire, it simply requires to be brushed, and is then fit for the cabinet.

Generally, however, we adopt more ready methods of producing the bronze; one of which is to brush the medal over with black lead, immediately upon its removal from the solution. It is then placed on the fire till moderately heated, when it may be smartly brushed with a hog's-bristle painting brush, the slightest moisture being used at the same time, in order to remove the black lead, when an uniform shining

bronze is obtained. There is no method of bronzing to be preferred to this for beauty, as a medal not two hours old displays the fine colour of antiquity so much prized by numismatists. In these operations, I believe an oxyde of copper is produced, to which the effect is to be principally attributed; it is a singular fact, that a medal can only be thus bronzed when fresh from the solution, for if it be allowed to remain unbronzed for a few days, it will not take the appearance by any contrivance whatever.

Instrument makers have a mode of bronzing the copper which is used for binding screws and other parts of their apparatus. It is simple and effectual, for the metal is simply to be rubbed over with a little weak solution of platinum, when the copper, or a portion of it is dissolved, and an equivalent proportion of platinum is thrown down. They generally protect this from change by varnish, but this should never be applied to delicate impressions. A solution of gold would answer the same purpose, did not its value prohibit its application.

Another valuable method of bronzing, is that by the application of a very weak solution of the hydro-sulphate of ammonia, or the sulphuret of potassium to the metal, when a sulphuret of the metal is obtained, which is of a very beautiful colour.

The object of all these methods is to throw up the fine workmanship, a result which is efficiently obtained in the colour given by the methods which have been described; the choice of these is left to the operator, but perhaps none excels, or even equals the mode of bronzing by black lead, when that operation is performed with care, and in the manner which has been described.

(187.) Zinc may be thrown down from its sulphate, by placing in a solution of this salt, the metal which is to receive the deposit. This is to be connected with the zinc of the battery, while another piece of zinc is connected to the silver. The depth to which the zinc ought to be immersed in the

solution, must be so regulated, that the hydrogen is about the point of its evolution. Rather a feeble current must be employed for this purpose. The reduction of the zinc is not of much importance in itself, although very interesting when considered with reference to the plates of galvanic batteries; for if one battery in a compound series, from any cause, has the whole of its exciting fluid neutralized, then will that cell be in the same condition as the apparatus employed for the reduction of the zinc, and immediately will zinc be deposited on its negative metal. This will occur with all the forms of batteries now employed, although it is a property of no consequence, as the action of the battery ought to be stopped before it has so thoroughly exhausted itself. When this deposit takes place, it can readily be removed by placing the plate in contact with any metal which can act as a negative plate to it. The necessity of this arises from the difficulty with which pure zinc is dissolved in acid. As soon as a dozen or more batteries, arranged as a series, have their exciting fluid saturated with sulphate of zinc, the zinc will be deposited on the negative plate, if a single battery only out of the whole number contain any acid; thus eleven batteries out of twelve may have their negative metal thickly coated, whilst the last will not have the smallest trace upon it. Zinc is never found in all the batteries of a series.

(188.) The salts of iron have a strong tendency to be peroxydised, in which state they cannot be reduced by the voltaic current. We must use therefore the proto-sulphate of iron; this is prepared very excellently for the use of chemists, as great pains are taken in the preparation of it. Every dispensing chemist prides himself on the excellence of his particular sample. The reason why this care is taken is owing to the circumstance that this salt will not turn black with tannin, while the mixture becomes ink with the per-sulphate. The medical man is very apt, from a deficiency of knowledge in chemistry, to prescribe, in conjunction with this salt, some vegetable substance, containing tannin, so that his unlucky

patient has the disgust of drinking a black inky fluid for his physic, if the salt contains the smallest quantity of the persulphate. But to return; the reduction of metallic iron must take place from a solution of the proto-sulphate. The metal upon which the deposit is to be effected, is connected with the zinc of the battery, whilst an iron nail is connected with the silver; the battery may vary from a single cell to a series of twelve or more cells; I prefer several cells. The nail is to be just so far dipped into the solution, that the minutest quantity of hydrogen, or none at all, is evolved from the metal to receive the iron; and after the lapse of a short time, the negative metal will become coated with metallic iron. The reduced metal is brighter, and rather whiter than polished steel, but it soon tarnishes in the air.

How far this will prove of importance for magnetic purposes, has yet to be determined. The reduction of this metal, and the means which I have pointed out to be necessary, again afford proof of the value of the laws which have been laid down in a former chapter.

(189.) Lead is a difficult metal to manage, for it prefers taking its own course to taking yours. It may be reduced from the acetate without crystallization, by using a very dilute solution of the salt, and acidulating it strongly with acetic or with a small quantity of nitric acid. The reduction of this metal is utterly useless, except as illustrating again the truth and universality of our laws. We may either use a series of batteries with a platinum positive electrode, or a single cell with a lead electrode.

(190.) Tin is as obstinate as lead, but may be conquered in a similar manner. The solution, from which the metal may be reduced, is the nitro-muriate, much diluted with acetic acid; we may use a single battery with tin for the positive-electrode, or several cells with a platinum positive-electrode.

(191.) We have now treated of the principles by which the most important metals may be reduced. We have seen that

the mode of generating electricity may be either by a simple circuit, where the substance to be used takes the place of the negative metal, to a piece of zinc continued in a porous jar, or by a galvanic battery, when the original mould acts the same part in a second cell. The particular battery to be employed, must be selected after a due consideration of the facts stated in the preceding book, but the principal points to be attended to are the properties of long continued action and simplicity. The foregoing details are the results of experiments performed with my own battery. The only influence which it has had upon these results, has been, that I have entirely devoted that time to the experiments themselves, which otherwise would in a great measure have been spent in the manipulation of other batteries.

BOOK THE THIRD.

ON ELECTRO GILDING, PLATING, &c.

General directions, 192. Voltaic gilding, 193. Single cell apparatus, 194. Battery apparatus, 195. Copper gilding, 196. Water gilding, 197. Gilding by amalgamation, 198. Voltaic platinating; Voltaic platinizing, 199. Voltaic palladiating, 200. Voltaic Plating, 201. On coating metals with nickel, 203. On coppering metallic substances, 204. On coppering non-metallic substances, 205. On coppering medallions, 206.—Fruit, vegetables, &c., 207.—Baskets, 208.—Earthenware, 209. On coating metals with iron, zinc, &c., 210. Conclusion, 211.

(192.) The infilming of one metal by another, is a subject of much interest, and the process has received different names according to the metal employed for that purpose. Thus, when gold is used, it is termed gilding; when copper, coppering; silver, silvering, or plating, &c. In every one of these cases we have to be careful that the two metals adhere, and for this purpose we take means to prevent any film of air remaining on the first plate, as that would cause a separation between the metals. We apply heat, we scour the plate, or where it is possible, we slightly act upon the surface of the metal to receive the new deposit, taking care thoroughly to wash the metal after this operation.

(193.) Voltaic gilding is, in most cases, remarkably easy, for if we take care to follow the laws which I have detailed, it will be attended with very little trouble. The metal to receive the gold, may be either platinum, palladium, silver,

copper, carbon, or gold itself. The surface should be chemically clean, and freed from adherent air, either by plunging it into nitric acid or a solution of potash, or by heating it and then quenching it in acid. The smoother the surface, the more favourably the deposit will take place upon it, for a rough surface is not well adapted for these operations, because the hydrogen has a great tendency to be evolved from them. When the metal to be gilt does not decompose the solution of gold, the solution may be stronger. When, on the contrary, the metal, as silver or copper, acts upon the solution, it must be weaker. The electrical current must be suited to these varying circumstances, and in general a very feeble one must be employed.

(194.) For gilding, De la Rive uses a single battery; that is, a porous tube as an inner cell, and the solution of nitro-muriate of gold in the outer cell. The inner cell in this case must be charged with water, to which about a drop of sulphuric acid has been added, and only a small piece of zinc should at the same time be employed.

For these operations, a diaphragm should be selected, which will allow only a feeble current of electricity to pass—thick bladder or thick plaster may be employed. A tube, as formerly described, with one end drawn to a capillary bore may be used for the same purpose.

The outer cell must contain a weak solution of nitro-muriate of gold, with a few drops of acid. Here the negative metal may be of considerable size with advantage, because that lessens the proportional quantity of electricity to each respective part of the metal. The negative metal, particularly if it be silver, copper, or their alloys, must not be in the fluid a moment before connection is made with the zinc, because in that case the silver would of itself reduce the gold by elective affinity, or by being itself dissolved, and then it will not adhere firmly.

(195.) All these methods appear to me very objectionable, and a far more manageable mode of gilding, is to take three,

four, or more, of my batteries, and charge them with very dilute sulphuric acid. At the two extremities attach platinum wires, one connecting the zinc of the battery with the metal to be gilt, the other forming the anode or electro-positive pole in the decomposition cell. (fig. 7.) The muriate of gold must be diluted and slightly acid. Into this, the platinum wire, which is connected with the silver of the batteries is to be placed, but it must be immersed only to a very trifling depth. Having thus completed these arrangements, the object to be gilt is made to communicate with the zinc of the battery, and immediately on its being placed in the solution, the gold will begin to be precipitated.

Every portion of the object on which we are desirous not to have the layer of gold, must be coated with tallow, wax, or any other non-conducting substance, which will prevent any deposit from taking place on those parts. In this way, an object may be coated up to any desired limit, or upon any circumscribed parts of its surface, as, for example, drawing or writing thereon. The rapidity of the process may be regulated to the greatest nicety by placing more or less of the positive wire in the solution, by which means, as in other cases, the quantity of electricity passing may be regulated with the utmost precision.

To conduct this elegant process with the greatest economy of time, the quantity of electricity should be so regulated, that the hydrogen is kept just below the point of evolution from the negative plate; for we must always bear in mind, that the evolution of hydrogen is attended with evil, as the precipitate will be in the finely divided state, or black powder.

During the process, particularly if the object have a rough surface, it is a good plan to remove it once or twice from the solution, and to rub it with a small quantity of whiting and well wash it; by these means, any finely divided metal will be removed, and the gold will be precipitated in a very even manner. The colour of the gold, if the precipitated layer be very thin, will be a greenish yellow, but when thicker it will be the

natural colour of the pure metal. A little copper added to the solution of gold will cause the precipitated metal to be very red. The preceding observations apply equally to those cases where we desire to gild platinum, palladium, silver, or gold itself.

(196.) To gild copper is more difficult than to gild silver, because a small quantity of copper is apt to be dissolved, thus rendering the gold exceedingly red; but still with a very dilute solution of gold, and by using the mere point of the positive wire, it may be effected. Slight differences in the arrangement, according to the nature of the object to be gilt, may be advantageously made.

When we desire to gild silver spoons, they are to be first thoroughly cleansed by the processes previously detailed, after which the backs and edges are to be slightly greased. The handle of the spoon will serve to make connection with the zinc of the battery, which must consist of at least three cells. Into the bowl of the spoon the solution is now to be poured, and immediately afterwards the point of a fine platinum wire, connected with the silver of the battery, is to be dipped into the liquid, when the deposition will commence. The interval of time which elapses between the placing of the solution in the spoon, and the completion of the circuit by the wire joining the silver of the battery, should be as short as possible, in order that no time may be allowed for the local action of the silver on the solution of gold, for should that unfortunately occur, the adhesion of the gold is impaired. The strength of the solution should not be too great at the commencement of the process, so that local action in the first instance may be prevented; but after a thin layer of gold is obtained, the solution may be of any strength.

The interior of any silver vessel may be gilt in the same way, be it ever so large, taking care, if the surface be very extensive, to allow more of the platinum wire to dip into the solution of gold. (fig. 7.) The exterior of any vessel may be gilt

placing the vessel in the solution as before described, but this does not require any further notice.

(197.) The process of gilding by galvanic precipitation, from a solution of gold, is very different in its effects from the method patented by Elphinstone, termed water-gilding; by the latter process the metal which is to be gilt is dissolved in a proportional equivalent to the gold deposited, and therefore as soon as a mere surface of gold is obtained, no farther deposition can take place; but when the gilding is effected by the galvanic battery, any amount of gold may be applied upon the object; a consideration of no small importance, as upon the thickness of the coat must depend the durability of the gilding.

It is not the solution of nitro-muriate of gold which is used for water gilding, but a solution of the oxide of that metal in potash. The solution may be prepared by adding caustic, potass, or its carbonate to the ordinary solution of gold, in such proportion that the precipitate first formed is re-dissolved, and then it is fit for use. When any article is to be gilt, after being first thoroughly cleaned, it is plunged into the hot solution, and a thin coating is soon obtained, at the expense of a small quantity of silver.

(198.) There are, besides these processes, other modes of gilding used in the arts; as gilding by amalgamation. In this case, a mixture of finely divided gold and mercury is rubbed over the object, and the mercury is afterwards driven off by heat. This process is very detrimental to the health of the workman, as the fumes of mercury are extremely poisonous. It is to be hoped therefore, that the process of gilding by the galvanic current, will, after a period, entirely supersede this most injurious operation. A comparison between the durability of gilding by the galvanic process, with that by the other methods, can only be made after the lapse of a considerable period; I find however, that some spoons and other articles which I gilt by the battery, wear extremely well. The thickness of the deposit can be regulated with the utmost accuracy,

from the thinnest possible layer to a coating of an inch in thickness. Electro gilding appears not to be generally applicable for non-conducting substances, for I have not at present succeeded in applying the gold to any extensive surface, although I have seen it grow, for a short distance, over black-leaded sealing-wax. Perhaps by using the strongest solution of gold, it may be possible to gild surfaces in that way.

(199.) Platinating metals by the galvanic current, is a new feature in science. The process is similar in all respects to gilding, but is more difficult. The solution of the nitro-muriate of platinum must be very weak, and the battery must be charged with dilute acid. The object to be coated must be very smooth, and thoroughly cleansed by potash, before the process is commenced. Having proceeded thus far, and the solution of platinum being ready, a very fine platinum wire, in connection with the silver of the battery, must be placed so as to dip into the solution, but must not be immersed beyond a very short distance. The object to be platinated is now ready for connection with the zinc of the battery, after which is effected, it is to be dipped in the solution. (fig. 7.) Immediately, oxygen gas will be given off from the platinum wire, in connection with the silver. From the copper or other metal to be platinated, no gas will be evolved, provided too much electricity be not generated. In a few minutes the object will be coated with platinum. During the process, the object should be withdrawn from time to time, and rubbed over with a little whiting.

This process must not be confounded with that by which the negative metals are prepared for my battery, for in this case, the platinum is precipitated of the colour and appearance of platinum, but in the latter case it is thrown down as a black powder. The first I propose to name platinating metals, in contra-distinction to platinizing. To platinize metals, we use a strong current to throw down the metal in the black powder; to platinate, we may employ solutions of any strength, but we must use more moderate currents.

The specimens which I have prepared of this method, will not resist the action of nitric acid, because there are generally some little fissures uncovered, some little crack which admits the nitric acid, which tears off the platinum in thin scales. It is not applicable to rough surfaces, as it is necessary that the surface for its reception should be smooth, if we wish to insure the absence of any black powder. The colour of the metal thus reduced is so similar to polished steel, that it would be difficult to distinguish the one from the other. It is needless to say that it has a very beautiful appearance. It would be of great value as a coating for telescopes, microscopes, quadrants, and a hundred other articles which must be exposed to the action of the weather.

(200.) To palladiate articles, we adopt methods similar in all respects to those used in platinating them. (fig. 7.) We employ the nitro-muriate of palladium in a dilute state, and apply the whiting, as in the former cases. This metal is whiter than platinum, but not so bright as silver. It might be used in the same cases, and with the same advantages as platinum; and we have besides, twice the bulk of metal in the same weight.

(201.) Silvering or plating by the galvanic current is difficult, but the means to be pursued are similar to those already pointed out. The surface of the object which we desire to coat, must be cleaned by solution of potassa, and then rubbed over with whiting; after which, it is ready for insertion in the fluid. The galvanic arrangements are similar, with the exception, that instead of a platinum wire, a silver wire should be used as the oxygen pole or anode, or in other words, that in connection with the silver of the battery. The object, as in those cases, must not remain a single instant in the solution whilst the circuit is incomplete. All further arrangements are similar to those described for gold, and do not require repetition in this place. The solution must either be a weak sulphate, acetate, or hypo-sulphite of silver, with a little dilute sulphuric acid. After the metal has been in the solution for two or three minutes, it will assume a dark colour, when it is to be

removed and rubbed over with whiting, and this process repeated, till a sufficient thickness of metal is obtained. The regulation of the quantity of electricity is important, and is best effected by using the finest possible piece of silver wire as the positive pole.

(202.) In the description given for coating other metals with a thin film of any of the noble metals, a weak solution has been recommended, as less likely to favour local action; but if we are desirous of coating any metal, where no elective affinity can take place, the metallic solution may be used of any strength.

(203.) Metals may be covered with nickel, by proceeding as in the former cases. The solution to be used is the nitrate of nickel, but this metal is not of very easy reduction.

(204.) Various substances, both metallic and non-metallic, may be coated with copper by the agency of the galvanic current. The solution to be employed, and the apparatus to be used, have been already fully described. The advantage of its application relates principally to non-metallic substances, which may, in this way, receive a metallic surface of pure copper. Not the slightest difficulty would attend the coppering of almost any metal; but as this is never likely to be required, there is no need to enter upon the subject.

(205.) Coppering non-conducting substances may de divided into two departments, the first of which contains those which require the deposit to assume, as nearly as possible, the form of the original substance. The second comprises those cases where the deposit is desired to be in a crystalline state.

A somewhat different arrangement is required in each case; for in the first, the battery and solution must be so arranged that the hydrogen is near the point of evolution; but in the second, the solution may be much stronger, and the quantity of electricity may be increased by increasing the size of the battery, and the surface of the positive copper pole in the decomposition apparatus.

(206.) In the first division we have delicate substances, such as medallions, &c. The substances of which the cast is made shonld be rendered non-absorbent by the processes already described. It is then to be brushed over with black lead, and at the edge, a very fine copper wire is to be once twisted, in order that perfect contact may exist between the battery and black lead. It is now ready to be placed in the solution of acidulated sulphate of copper, the end of the wire having been first connected with the zinc of the battery. After this has been done, the last thing is to place a piece of waste copper in the solution, of about the same size as the cast, and to connect it, by means of a wire, with the silver of the battery. (fig, 3, fig. 4.) Action will immediately take place, the copper will be dissolved, and the metal precipitated on the black lead of the object, spreading over the surface till the whole is covered It is as well perhaps, to use two batteries arranged as a series for this purpose, as that will ensure the uniform spreading of the copper over the medal. The medal must not be left in long after it has been coated, as that will detract much from its sharpness and beauty; after it has been taken out, it may be rubbed over with coarse paper to remove any little asperity that the copper has thrown up. To the numismatist this process will appear barbaric, as he would consider that it would detract from the beauty of the medal; but though decidedly detrimental, it is not so injurious as might at first sight appear to coarse objects, because as the copper is of nearly uniform thickness all over, the effect is to increase in size the whole design. To the sculptor and architect perhaps, it might be used with advantage to coat statues or other ornaments.

(207.) A pretty application of the art of coppering, is suitable to horticulturists, as by its means, fruit, vegetables, leaves, seeds, and various other specimens may be coated with copper, either for ornament, or for the purpose of illustrating the size, form, and other peculiaritics of the object. Apples and pears may be very readily coppered; they are to be

brushed over with black lead, and then a small pin is to be thrust in at the stalk; to this a wire should be attached, which is connected with the zinc of the battery. It may then be placed in the solution, and the whole arrangement completed by the insertion of a piece of copper, which is to be connected with the silver of the battery. In a similar manner, cucumbers, gourds, potatoes, carrots, and a hundred other vegetables, seeds, and roots can be covered. The form, after the process, is so characteristic as to mark strongly the individual character of each. The condition in which the copper is thrown down, can of course be varied according to the laws set forth in the last chapter. For ornamental purposes, the crystaline copper is the most beautiful, but for a specimen intended to illustrate the form of the object, the smooth copper is best adapted. After the objects are completely covered, the pin is to be withdrawn, which will leave a little hole, and that enables the evaporating juices of the vegetable to pass freely out, and thus promotes the complete drying of the encased object. A cucumber which I coated during the past summer, appears now to contain scarcely any thing inside the copper, and the pears, apples, &c. consist of little else but the metallic coat. The botanist will readily perceive in what way this process may be employed for his advantage.

(208.) A beautiful effect of metallic surfaces may be obtained by the deposition of crystalized metal on baskets. The wicker work must be blackleaded, and connected by means of a wire, to the zinc of a galvanic battery, when on being immersed in the metallic solution, and the circuit completed, it will be covered with the most beautiful crystals of copper, sparkling in the light from the facets of thousands of little crystals. It is as well to pass a very fine copper wire round several parts of the basket, so that it may touch the black lead in several places, for this will insure the coating to be more rapidly complete. Any other mode of giving a conducting surface, will answer equally as well as black lead. The copper pole for these objects should be very large, and a

series of two or three batteries employed. The solution of sulphate of copper should be perfectly concentrated, for all these circumstances will tend to render the copper crystalline. Baskets thus prepared, and filled with metallic fruit, leaves, insects, &c., might be used as ornaments for the drawing room, and would greatly exceed in interest the usual appendages; for if these objects were made by the individuals who possessed them, it would show his interest in the noble science of galvanism; and if they were purchased, it would be the means of encouraging the application to the arts and manufactures of this powerful agent. It is indeed, now but a small germ, but will doubtless become a vast tree, which by bearing fruit will cause a great revolution in the manufactures of this country. Let the attention of the wealthy be directed to the subject, and let them patronize the ornaments made by these means, and then speedily will the artizan become more perfect in his work, and the galvanic fluid will be as commonly used as steam or gas. I particularly dwell upon these circumstances in this place, because some coppered objects have been exceedingly admired, and many of them could not possibly have been made by any other process heretofore known.

(209.) Earthenware, or any other similar substance can be coated in like manner with the metallic copper, but when these smooth surfaces are to be covered, some difficulty arises, which may be overcome by the previous application of a very little varnish. In this way, by coating a jar with copper, a Daniell's battery may be made.

(210.) Metals may be coated with tin, lead, iron or zinc, in all of which I have perfectly succeeded by taking care that the deposit took place with such rapidity, that the hydrogen was not far short of its evolution, but not so rapidly that the gas was evolved. All these facts show the truth of the laws which we have before explained. In fact, I have succeeded in coating copper with almost every other metal by following the means which the laws already pointed out, dictate. Some

of these metals I found to be much more troublesome than others, and some will only give an irregular coating, yet, by following the principles explained in a former book, any metal may be thrown down in the reguline state, with more or less success.

(211.) Some metals have a great tendency to crystallize, which must be remedied by using their solutions, largely diluted with acidulated water. The voltaic reduction of these metals is never likely to be employed, and therefore it is quite unnecessary to enter into the processes minutely.

The facts in this book are generally new, and their application is extremely interesting; for to those who follow galvanic science as an amusement, the exercise of the arts of gilding, plating and coppering, will not only be interesting but useful; in the arts doubtless they will assume a higher importance, and add new branches for the successful application of electricity. Those who are desirous of following these processes as a business, will find that practice alone will make them perfect; and as the scientific man details the principles to be pursued, so the mechanic must follow these laws, and regulate the details as his extended experience may dictate.

BOOK THE FOURTH.

ON VARIOUS APPLICATIONS OF THE REDUCTION OF METALS BY GALVANISM.

CHAPTER I.

ON THE MULTIPLICATION OF COINS AND MEDALS.

Value of electro-metallurgy for the numismatist, 212. Mode of obtaining the mould, 213.—Directly by the voltaic current, 214.—By lead, fusible metal, &c. 215.—By non-conducting substances, 216. Metallic duplicates of gold, 217. Silver medals, 218. Medals of platinum, 219. Copper medals, 220. Precautions to be taken to prevent air bubbles, 221. Apparatus to be employed, 222. Single cell apparatus, 223. Thickness of the metal, 224. Removal of the cast from the mould, 225. Value of electro-metallurgy for medallists, 226. Additional advantages, 227. On the modes of making perfect medals, 228.

(212.) To the numismatist, the reduction of the metals by galvanism is of the highest importance, for on the one hand it presents him with the means of having casts of coins or medals, which on account of their great rarity he could never otherwise possess, and on the other hand it offers to the coin manufacturer the means of forging the more scarce coins, so that the collector must be doubly careful in making his purchases. At present, I am afraid that our art in unskilful hands, has been the means of destroying so many medals, that no benefit which has yet accrued has been able to compensate for their loss.

(213.) There are three methods of taking the duplicate of a coin or medal. By the first, a primary cast or an intaglio

is made in metal, directly by the galvanic precipitation; by the second, a metallic cast of the medal is first obtained, either in fusible or type metal; and by the third, we make the intaglio cast in some non-conducting substance, as white wax, sealing-wax, &c.

(214.) To take a primary cast at once from the medal or coin should not be attempted by an inexperienced hand, and never by any one from an unique specimen, for fear of any mischance. The process, however, is simple, and very valuable, when we desire a very perfect intaglio impression of any coin or medal. The object to be copied is to be coated on the side where we do not require action to take place, with grease, wax, varnish, or other non-conducting substance. A very fine wire is to be passed round the rim, and then it is ready to be placed in the metallic solution. The adhesion of the air to the metal is of considerable importance in this case, and the metal should not be allowed to remain a single instant in the solution before the galvanic circuit is completed.

The obverse and reverse can be copied by two operations, or even both by one, taking care to grease the rim, so that the whole medal may not be confined by the new deposit. This operation gives us two moulds, one of either side of the coin or medal, in intaglio. By this process a copper medal or coin is liable to have its bronze removed, but a gold or silver one will not suffer the slightest injury. This mould may be used for making plaster casts, sealing-wax impressions, or it may itself be again used as a mould to receive the galvanic precipitate, and we may thus obtain a very perfect relievo copy of the original.

(215.) Intaglios may be taken off coins or medals in lead, pewter, fusible metal, tin foil, or silver leaf in the manner pointed out in the preceding books, and these intaglios are then to have a wire either soldered or placed in connection with them, when they will be ready for the reception of the metallic precipitation. (134, 135.)

(216.) The third method, however, is the one which should

generally be adopted, for by non-conducting substances we can obtain most excellent moulds for receiving the precipitation. For coins, very small medals, and cameos, impressions in good sealing-wax, are to be preferred by the amateur. (136.) These must have a fine wire melted into the wax, and be blackleaded, and then they are ready to be copied. (144.)

Larger medals may be copied in wax, bees-wax and rosin, or plaster of paris. The plaster of paris must be rendered non-absorbent by any of the processes given in a former book; tallow or spermaceti are best adapted, and from their being always at hand, are to be preferred. They are then to be blackleaded, when they may be placed in the solution. By either mode, perfectly sharp medals may be taken. To the workman who requires to make a large uumber of metallic impressions of coins, I would recommend the use of a square piece of plaster of any convenient size, say six inches each way, with impressions of medals as thick as he can put them. This might be easily managed by joining separate plaster moulds together till the size is obtained. This piece must be filled by the processes given before, blackleaded, and lastly, the metal is to be thrown down upon it. By this means he will obtain a sheet of coins, which he may either retain in that form, or by cutting them out may have each separately. The copper thrown down upon plaster is quite as perfect as the plaster cast. Melted stearine candles will also answer for making moulds.

(217.) Having determined upon the process to be adopted, the operator has next to decide of what metal he will make his duplicate: For a gold medal, a gold or silver surface will answer to receive the metal precipitated from its nitro-muriatic solution. Where the first of these metals is employed, we should use as strong a solution as possible; and the coin to be copied is to be connected with the zinc-end of a series of from four to twelve batteries. A very fine platinum wire, immersed in the solution to a trifling depth, is to be connected to the platinized silver of the battery, when the deposit will take place. For a mould of either a coin or medal in silver,

the solution should at first be very weak; but as soon as a moderate surface is obtained, the strength of the solution should be materially increased. A very useful mode of the application of gold, would be, first to throw down only a moderately thick layer, and then to fill up the deficiency by throwing down copper upon it. This, to the false coiner, might form a valuable piece of information, but is here mentioned to put people on their guard.

(218.) Medals, made entirely of silver, are apt to be brittle, but by coating the back with copper, we have all the advantage of a silver surface, combined at the same time with strength and cheapness.

The solution of the sulphate, nitrate, or acetate, may be employed. A silver wire must be connected to the silver of a single battery, and the object to be copied must be joined by a fine platinum wire with the zinc of the battery. The larger the medal is to be copied, the more readily will the deposit take place, because a larger negative metal will be exposed to the fluid. A saturated solution of the sulphate may be employed, but with the nitrate, a solution containing about twenty grains of the salt to the ounce of water, will be found sufficient, although it may be of any strength whatever, by regulating the quantity of electricity according to the laws. Farther details, relating to the modus operandi, have been sufficiently entered into, when speaking of the salts of silver. (172.) This process is not applicable to any but a gold or silver surface, for the reduction cannot be well effected on non-conducting substances.

(219.) Medals may be made of platinum or palladium entirely, as in the cases just mentioned, or a duplicate cast of the medals may have an exterior of either of these metals, whilst the interior may consist of copper. The mould for these metals may consist of either gold, platinum, palladium, or silver. The solutions may be of any strength, although the operator will find the strongest the best adapted. See the general remarks on platinum, palladium, &c. (169—171.)

(220.) Copper is the metal of most importance to numismatists, for that will answer both for metallic and non-metallic surfaces. The salt which may be used for ordinary purposes, is the sulphate, and when used for this purpose, the solution may be more concentrated than when the reduced metal is required for the electrotype. A saturated solution of sulphate of copper, mixed with one-third of its measure of dilute sulphuric acid will answer admirably for general purposes.

(221.) In making medals, we must be cautious that no bubbles of air adhere to the mould, or be carried down into the solution when the mould is immersed. This is very apt to occur when the mould is very deep, as sometimes a layer of air bubbles may be observed adhering in the hair, the beard, or even at the top of the nose; a circumstance which would not a little impair the features of the copy. To prevent any occurrence of this nature, the medal should be inspected after it has been in the solution a short time, and any bubble dispersed. If this be not attended to, the bubbles would become quite encased with copper, and a little hole left.

(222.) The battery process is without doubt the best for making medals, but the form of the precipitating trough must vary, according to the size and form of the medals to be made. For very large medals, say six inches in diameter, a common earthenware basin is the best. The medal is to be connected with a wire, and placed flat at the bottom of the vessel, and this wire is to be connected with the zinc of the battery. A piece of copper is now to be procured, which must be somewhat larger than the medal above which it is to be placed in the basin. The peculiar form of the basin will of course prevent the copper from descending upon the medal, a result which is carefully to be avoided. This copper is to be connected with the silver of the battery. The solution is then to be poured into the basin, when action will immediately commence; the copper will be reduced upon the mould from the solution, and copper will be dissolved from the positive pole, to keep up the

saturation of the fluid. It is always necessary to employ a battery sufficiently large; two or three times the surface of negative metal is most favourable for precipitation, though by following the principles already given, any sized battery may be employed. For small medals I greatly prefer the battery process. In this case the vertical precipitating trough may be used. (fig. 6.) A piece of copper, connected with the silver of the battery, is placed on one side, and on the other, as many medals may be placed as can be arranged opposite to the copper; and these are all to be connected with the zinc of the battery. The advantage of this mode of proceeding over all others, is the facility given to the operator, either to remove or add one or more medals, without any injury to the others; and eight, ten, twelve, or even many more, may be made at once.

(223.) Although the battery process is generally to be preferred, yet it does not follow that it is the only mode capable of being adopted. The single cell apparatus is also adapted to medals. (fig. 1.) (fig. 2.) Either of the forms of apparatus which have been here described may be used, and the only general rule to be adopted is, to take care that the sulphate of copper be concentrated, the zinc sufficiently large, and the distance of the zinc from the mould not too great. A little acid added to the sulphate of copper, will generally improve the quality of the reduced metal. (107—113.)

(224.) By any of these processes we can obtain a perfect cast from our mould; yet if the device on the mould be very deep, the deposit will not always take place favourably on the deepest parts. In these cases, when the medal is nearly completed, we may remove it from the solution, wipe it dry, and coat the parts most thickly covered with any non-conducting substance. The medal is then again to be placed in the solution, when the deficiencies will be soon filled up.

Great thickness of copper is not required for medals; for if it be as thick as a wafer, and of good quality, it will amply suffice. For most purposes it is of no advantage to have it thicker, and when we are desirous of strengthening the deposit,

the back may be coated with sealing wax. All these details must be regulated by the fancy of the operator, but I think that the deposit obtained in twenty-four hours is amply sufficient.

(225.) The last operation is the removal of the cast from the mould, which is attended with no great difficulty. We must be careful to remove any copper which embraces the mould at the edges, and then, by pulling the one from the other with moderate force, a separation will be effected. When the duplicate has taken place upon the original medal itself, the adhesion will be very slight, if the precautions are taken which I have before detailed. Casts made from most non-conducting substances come off sometimes so readily that the mould is not the least injured. The adhesion indeed is greater when leaden moulds are used, yet, with care, the duplicate may be removed without much detriment to the mould, although it is always more or less impaired. In every case some judgment is required to regulate the direction in which we make the pulling force, according to the manner in which the prominent facts are arranged; for generally there is one way where the cast can be removed more easily than any other. To copper, &c., there need be no adhesion. (125.)

(226.) The importance of electro-metallurgy for the manufacture of medals, to many is perhaps by no means evident; but when they are informed of the difficulty of striking off large medals, it will be immediately apparent. Mr. Haggard has in his possession a very fine medal of Boulton, about four inches in diameter, and he assured me that no less than three hundred blows were required to insure a perfect impression. Here the value of electro-metallurgy is pre-eminently apparent; for by the galvanic process, no more difficulty would attend the manufacture of this medal, than that of the most simple.

(227.) Again, there are many persons distinguished for their learning, their abilities, their public station, or what is above all, their private virtues, a medallion of whom would be

greatly esteemed by their friends. Now the expense of engraving a steel die is such that it precludes the idea altogether; but as soft substances can be copied by the galvanic process, the expense of obtaining a medallion in wax, when divided among thirty or forty persons, would surely not be a material object, and they would be thus enabled to possess a likeness of the person so much endeared to them. What a contrast would there be between the distribution of the portrait of a deceased and esteemed friend, and the unmeaning custom of giving a black and gold ring, simply bearing an inscription. How much better would the remembrance be perpetuated! for the ring is valued more frequently for its size and intrinsic worth, than for the remembrance it is intended to convey; and after having been worn for a year, is too frequently cast, without remorse, into the melting pot. A copper medal on the contrary, no matter how beautiful its execution, would intrinsically be worth only a few pence, and frequently would be far more prized and taken care of by the possessor.

(228.) It is a great desideratum to be enabled to take a perfect coin or medal by the electrotype, that is, one having both obverse and reverse; as yet this has not been obtained, and from my experiments, it appears to me to be very difficult. The manner in which I have attempted to attain this object, has been, to procure casts of both sides of a medal, and to place these in contact at the part of the plaster external to the impression, in such a manner that a distance intervened equal to the width of the coin; the inner surface of the plaster casts was then blackleaded, and connected with the zinc of the battery, whilst the piece of copper to be dissolved was placed above a little hole left in the rim of the plaster mould. In this position the casts were connected with the silver of the battery; but the process, with me, did not succeed. I conceive however, that it is possible by this method, to make a thick medal, with both obverse and reverse.

CHAPTER II.

ON COPYING SEALS, PLASTER CASTS, &c.

Value of a seal, 229. Process for copying a seal, 230. Copper moulds from plaster medallions, 231. Quality of the reduced copper, 232.

(229.) In former times, when the art of writing was an extremely rare accomplishment, a seal was an instrument of great importance: it fulfilled the same purpose, at the end of a conveyance or deed, that is now accomplished by the written names of the parties; which even now, in reference to the ancient custom, are termed signatures. No business was performed without the seal, no corporation existed without this appendage. The extraordinary seal of Southwell, which required three separate dies to form one impression, is a good instance of the important functions of the seal; for the three parts being in the respective hands of three trustees, it required the concurrence of all, before a perfect impression could be made; and consequently, before any land or other property under the trust could be disposed of. Now the value of the seal is nearly lost, and in the great establishment where I reside, thousands of pounds hourly change hands without any such ceremony; a faint representation only of the seal being made by a black wafer, a bare relic of former customs.

(230.) Now that seals are nearly valueless, there can be no harm in describing the process of copying them. This is very simple; we first give them the thinnest film of black lead, with a hard brush. If necessary, this may be aided by cautiously applying the most minute drop of spirits of wine, but it should be avoided if possible; for the wax being soluble in alcohol, the seal is liable to more or less injury. A fine metallic wire is now to be heated over a candle, and the hot end placed in contact with the rim of the seal, so that it may adhere. Care must be taken to apply a little plumbago round the point of insertion, so that it may be continuous with the

wire. It is then ready to be placed in the solution. This part of the operation is similar in all respects to that required for the moulds of coins. (220, 221, 222.) (fig. 6.)

The largest seal, as the great seal of England, or the large seals of the bishops, may in this way, with ease, be copied; and the smallest are attended with no more difficulty. The operator must remember, that although he is at perfect liberty to copy the Chancellor's seal of the last reign, yet he would be liable to the utmost penalty of the law, if he were to carry on his scientific proceedings upon the great seal of Her present Majesty. A letter received in the morning may be answered the next day, or even the same night, by a letter sealed with an electrotype impression of your friend's seal. If a relievo be required from a sealing wax relievo, it may be obtained by a double electrotype operation, or by first making a plaster intaglio, and proceeding with that as for plaster generally.

(231.) Copper casts may be obtained of the utmost perfection, from plaster medallions. If we desire to take a copper mould or intaglio from a plaster relievo, we simply prepare the plaster by tallow, wax, or any other similar substance. We then carefully apply the black lead, and twist round the rim fine wire to connect it with the battery, after which it is ready to be placed in the solution. The copper copy is by these means as perfect as the plaster. When a relievo of a plaster medallion is desired, we may either electrotype the copper mould, obtained as before, or we may make a mould of white wax, having first filled the plaster with water. The wax mould is to be blackleaded, and must have a wire attached to it, before it is put into the solution. The compound of bees wax and rosin may be used for the same purposes, its application being similar to white wax. The copper medal produced by any of these means is quite perfect, and the process is an excellent one; for it is neither attended with difficulty, nor does it require much labour, and is performed without the slightest detriment to the original plaster medallion. The

whole difficulty attending the multiplication of works in plaster, is not the manufacture of the copper duplicate, but the trouble of obtaining the plaster itself perfect. It is singular, that every artist who uses this substance, considers that he is possessed of some secret; but in reality, the working in plaster is an art acquired by practice, and requires judgment in different cases; but not a science dependent upon certain laws.

From a plaster cast we can obtain a stereotype mould, and from this a medallion in copper; but few now would be inclined to follow this method, when the others are so well adapted. The apparatus and modus operandi is similar, in all respects, to that employed for the multiplication of coins and medals. (220—222.) (fig. 3.) (fig. 5.) (fig. 6.)

(232.) The reduced copper for the foregoing objects can be made of any texture that may suit it best. It may be either produced of the greatest flexibility, or of the most extreme hardness, by following the laws which we have laid down. A very hard medal, cameo, or seal, is best obtained by using a very strong solution, a very large single battery, and a very large positive copper pole. It might be very useful for Bates' Anaglyptograph, an ingenious instrument, by which a correct engraving of any raised object can be executed. A point is passed over the medal, at an angle of 45°, this communicating a motion to another diamond point. As the point passing over the medal is raised or depressed, the diamond point takes a corresponding curve, so that the lines ruled on the plate form certain curves, the effect of which is to give a correct drawing of the medal. When a thin layer of black lead is used, the deposited copper will not, in the slightest degree, be discoloured by it, although it will always be taken into it, leaving none on the prepared plaster. If a very thick layer of black lead is employed, the copper will be discoloured.

CHAPTER III.

ON THE MULTIPLICATION OF BRASSES.

Process for obtaining Duplicate Brasses, 233.

(233.) There is scarcely a church in the country which has not some curious old monument, where characteristic likenesses of a whole family are engraved on a brass plate. To the Town Council of Yarmouth these relics were of so little interest, that they condemned the whole collection from one church to be applied to the manufacture of standard weights for the use of the town. By antiquaries however, these monuments are highly prized, and many would be delighted to possess a fac-simile of many of these objects. This may be accomplished by comparatively simple means. It is only necessary to take a cast of the brass in plaster of paris, having previously oiled the brass; the plaster is to be well dried, and then soaked in tallow. A wire must now be passed round it, and black lead is to be applied with a soft brush, when it is ready to be connected with the battery (fig. 3.) Only moderately sized brasses can be copied in this manner, for some are so large, as that of the Archbishop of York in Chigwell church, in Essex, that they would require such a large vessel to contain it, as virtually to render the manufacture of a duplicate almost impossible.

The battery process is best suited for these purposes. A large piece of refuse copper must be employed for the positive pole, and it should be placed as near the plaster as possible. As a large surface of plaster is generally required to be copied, a large battery will be required, or otherwise the strength of the metallic solution must be regulated to the power, and rendered much more dilute and acid.

CHAPTER IV.

ON MAKING DIES FROM EMBOSSED SURFACES.

On metallic reverses from raised surfaces by galvanic agency, 234. Peculiarities of dies made from paper, 235.

(234.) All embossed surfaces may be copied with facility, whether they consist of paper or any other substance. They must be first rendered non-absorbent by oil, varnish or wax, according to the thickness of the texture; linseed oil perhaps is to be preferred for paper. It must be allowed to dry before the black lead is applied to make it ready for the solution.

(235.) Dies made from paper generally exhibit a slightly dented appearance in the smooth parts, from the little projecting points of the paper having been copied. This, I am informed, disappears after many impressions have been printed. Doubtless the attention of the commissioners of stamps and taxes has been drawn to the fact, that the stamps can with great ease be copied by the electro-metallurgist, but it must remain with them to consider whether any attention to the subject is requisite.

CHAPTER V.

ON THE MANUFACTURE OF MOULDS FROM FRUITS, VEGETABLES, &c.

On making moulds from vegetable substances, 236. Chantrey's method, 237.

(236.) In a former book, means were adverted to for coating various kinds of fruit, vegetables, and leaves, with metallic copper, having first blackleaded them. (207.) By simply carrying on the process, until a thick deposit be obtained, instead

of merely coating the object, a mould will be obtained for any purpose required. A cast thus taken of a leaf, for instance, that of a Morel cherry, baffles all description. The copy is absolutely perfect; every fibre and nervure, in fact the minutest part is cast in copper with the utmost fidelity; and in the same way the surface of fruit may be correctly copied, so that every excrescence or depression, however minute, will be as apparent as in the original.

(237.) Chantrey has a very ingenious, though a troublesome and complicated method, of obtaining a cast of leaves or sprigs of trees; he takes the finest river sift, ground up, and encloses the leaves and sprigs in it; the whole is then dried and thoroughly baked, by which process the wood is carbonized, when a strong blast of air is sent through the apertures, which removes the carbon, and leaves a cast of the object, and that serves as a mould, into which he pours his melted copper. The same end might be attained far more readily by the galvanic current.

Every vegetable and animal substance whatever, which will remain undecomposed in the solution of copper for a few hours, can have a metallic mould made from it. For all these cases, the battery apparatus, similar to that used for medals, is the best. (fig. 3.)

CHAPTER VI.

ON THE APPLICATION OF ELECTRO-METALLURGY TO SCULPTURE AND OTHER PURPOSES.

The mode the sculptor adopts to obtain a metallic cast, 238. On making a metallic cast by electro-metallurgy, 239. The texture of the copper, 240. General remarks, 241. On the application of electro-metallurgy for goldsmiths, 242. For surgeons, &c., 243.

(238.) Unfortunately the British public have nearly ceased to patronize British sculpture, otherwise electro-metallurgy

would be a valuable assistant to that art. The sculptor first makes his model in clay, from which he takes a cast in plaster, and this again serves as a mould, into which he pours his fused metal. This latter proceeding is attended with much trouble, and not unfrequently with great danger, from a risk of explosion. The metallic cast when made, is by no means perfect, as it requires much labour to finish it.

The electro-metallurgist could obtain a far more perfect cast at once, by simply preparing his plaster, blackleading it, and placing it in the solution of sulphate of copper. A wire in contact with the black lead must communicate with the zinc of the battery, whilst the sheet of copper to be dissolved should communicate with the silver.

(239.) For very large designs, an inconveniently large vessel would be required; to obviate this difficulty, the mould, provided it be hollow, might have the separate pieces of which it is made, so joined together by wax or grease, that itself should form the vessel to contain the liquid. Very large batteries ought to be employed by the sculptor, and rather a dilute solution; because in all probability the size of the battery will not be proportionate to the immense surface exposed in even a moderately sized design. The piece of copper, forming the positive plate, should be as large, and as close to the plaster mould as it can be placed, in order that as little impediment as possible may be afforded to the passage of the current.

(240.) The copper may be of any thickness; and its strength and thickness may be regulated as required in different parts, by increasing or diminishing the distance between the plaster and the positive plate of copper. The relative cost of this method of making a bronze figure, over the plan now in use, is perhaps difficult to estimate accurately. By the old plan a bronze figure costs the value of the copper, and the coals required for its fusion, besides the labour requisite to render the metal cast perfect afterwards. By the galvanic method, it would cost the value of the copper, + the value of an equal

weight of amalgamated zinc, + the cost of the labour required to work the batteries — the value of the sulphate of zinc formed. From the above statements, a rough idea only can be formed of the relative costs of these two methods in practice, and it can only be determined with certainty by very large operations.

(241.) Before bringing this book to a conclusion, I may mention that the application of electro-metallurgy, or the art of working in metals by the galvanic fluid, is not confined to the foregoing subjects; for every kind of object, which can possibly be made in copper by any other method, can also be made by electricity. With regard to the use of other metals for the like purpose, they can in some instances be employed; but still, the application of the galvanic fluid to the working of these must be limited, because the intrinsic value of many is so great, as to preclude their general use; whilst the value of others is so trifling, as to render their application of little value.

(242.) To workers of gold electro-metallurgy promises to be of great value, for after once having procured a mould, he can obtain the most elaborate devices; but still, in buying manufactured articles of gold, the intrinsic value of this metal is so great, that the workmanship forms frequently but a small part, or otherwise electro-metallurgy would be of the utmost importance to the goldsmith.

The dentist requires for artificial teeth an exact cast of the mouth, in gold, platinum, or palladium. Now the cost of the manufacture of this is so expensive, that many are prevented from availing themselves of these valuable appendages. It is absolutely necessary that the gold should fit very accurately, or else the possessor is not able to use them. Electro-metallurgy might be brought to aid the mechanic in this matter, but the operator must recollect that notwithstanding the scientific principles detailed in this work, considerable skill in the manipulation is required.

(243.) Even to the surgeon, electro-metallurgy appears

likely in many cases to be very valuable; for when he is desirous of exerting constant pressure on any part, or of confining any part in a particular position, he can make a copper instrument exactly to suit any individual case which may occur, by first taking a cast in plaster of paris, or which will be more simple, by a piece of gummed sheeting.

To the geologist, electro-metallurgy is not without its interest, for independently of the rationale which it affords of the veins of metals embosomed in the earth, it gives the means of obtaining in copper, casts of any fossil which will remain unacted upon in the metallic solution. If the solution is acid, of course it will be unsuitable for any strata containing carbonate of lime; but then, by first taking an impression in plaster, a metallic reverse can be taken from it, which will be a perfect fac-simile in metal of the original. These metallic casts are preferable to any other kind of duplicate, because they occupy less bulk, are lighter, more indestructible, and less fragile than any other material.

BOOK THE FIFTH.

ON THE ELECTROTYPE.

CHAPTER I.

ON THE MULTIPLICATION OF TYPE.

The mode of printing books, 244. On stereotyping, 245. On electrotyping the type, 246.

(244.) The ordinary type, such as this work is printed with, has each letter separately cast of a particular alloy; and these letters when combined together form words; again, a number of the words form a paragraph—a series of paragraphs a chapter,—a number of chapters a book—and lastly, several books form this volume. Most works are printed in parts; thus whilst I am writing this chapter, the second book is completely printed, and the types distributed; whilst the proof of the third is lying on my desk to receive such alterations as may occur to me. Now the electrotype would be of no value to the printer in this case, for the same type which is used for the first part of this work, will be again used for the last, and even after the whole is printed, will be very little impaired.

(245.) With books which have a very large circulation, as the Bible or Prayer-book, and where no changes are required in the matter for a series of years, it is usual, after the work is completely set up in the type, to take a stereotype copy of it. A plaster mould of the type is first obtained, which is thoroughly baked in an oven, and from it a metallic cast in stereotype metal is made, which is an exact copy of the ori-

ginal. The duplicate thus obtained, has advantages over the type; for every stereotype page is in one piece, whilst the type is made up of as many different pieces as there are letters. This can be done so cheaply, that the electrotype can never compete with the stereotype.

(246.) To procure an electrotype copy from a page of type, we have to take an intaglio impression from the type, either directly in copper, or we may make it with plaster, and afterwards render it non-absorbent, or we may take it in white wax: the intaglio impression may be blackleaded and placed in the solution, to receive the deposit of copper. This process is only likely to be useful for Bibles, and probably it might be found to wear longer than the usual stereotype metal, but at present we have no experience on that matter.

CHAPTER II.

ON THE MULTIPLICATION OF PLAIN COPPER PLATES.

(247.) The application of the electrotype to the various departments of engraving, is of the greatest importance, and the new field open in this branch alone, is very extensive. Engravings generally are made upon copper plates, which have undergone a tedious preparation. The copper, which is to be employed for this purpose, should be as pure as possible; it has first to be rolled to a certain thickness, after which it passes into the hands of the copper plate maker. He carefully examines the plate, and picks out any little piece of foreign metal he may chance to perceive, and then fills up

the gap by dexterously hammering around it, so that he draws the neighbouring copper over the hollow. The plate is then well hammered, and receives a rough polish by charcoal. The price of a plate so manufactured, is worth from two shillings and sixpence to three shillings and sixpence per pound.

(248.) This copper plate is by no means pure, as it generally contains tin, and other metals which render the engraving sometimes difficult, and the etching very uncertain. To obviate these faults we make an electrotype plate on one of the prepared copper plates, and as the metal of this is absolutely pure, it is found to be far better adapted for the purposes of the engraver. This duplicate plate possesses the same surface as the original, and may therefore be at once used; but it is found better to hammer the duplicate, and prepare it with charcoal, as that greatly improves it, by making it more elastic; and it is the opinion of one of the first plate makers in this city, that the hammered plate will work as well as steel.

One of these electrotype plates was hammered and prepared as plates ordinarily are for engraving, when Mr. Palmer had various specimens of art executed upon it. First, the plate maker's opinion was taken of it, and he decided that it was vastly superior to the common copper; here we may remark, that many persons have doubted whether the electrotype copper would bear hammering; now this is the strongest proof possible, for the whole of this plate was thus prepared. The plate was then sent to a letter writer, to receive a specimen of this species of engraving, as well as to have his opinion of it; he stated, that the quality of the copper was such, that much less labour was required for the process which it had to undergo. It was then sent to an etcher, and he found it greatly superior to ordinary copper plates; for the nitric acid bit with the utmost uniformity on account of the purity of the copper. A specimen of machine ruling, rose-engine turning, and medal ruling executed by Bates's patent

anaglyptograph was then executed, and the opinion of all the artists concerned in the work was the same; for the superiority of using pure copper, over the ordinary copper which is usually contaminated with other metals and charcoal, was apparent to all.

(249.) The exact process by which these electrotype plates may be prepared, is very simple. The plain plate on which the deposit is to take place, is to have a flat band soldered on its back, in order that efficient connection may be made with the zinc of the battery. Now the heat necessary to effect this, drives off the air which infilms the metal, so that if it were placed at once in the solution of sulphate of copper, the two plates would stand a very fair chance of adhering to each other. To prevent this serious evil, the plate which has been soldered, ought to be placed in a cold place for twenty-four or more hours, which will enable it to regain a second time its film of air. Those who are not skilful in soldering metals, may simply place a wire or piece of metal in contact with the back of the plate, as that connection will be amply sufficient. Every part of the plate which is not intended to receive the deposit, must be covered with tallow, wax, or any other non-conducting substance.

(250.) Having thus prepared the plate, a platinized silver battery, which exposes about twice the surface of negative metal, is to be charged with dilute sulphuric acid, consisting of about one pint of strong sulphuric acid in two gallons of water. By using the acid thus dilute, the risk of much local action is materially lessened, and for the same reason the acid should never be poured into the battery till it is quite cold. The best form of battery for these purposes is fig. 3 A. The silver has a binding screw soldered to it, and a piece of wood is fixed on its upper part. The zinc is placed on each side of the silver, and consists simply of two strips which have no solder attached to them, but are connected to each other, and to a binding screw by a large screw, which embraces at once the two zincs, and intervening piece of wood fastened on to

the silver. This very ingenious arrangement appears to have been devised by the instrument maker, from a necessity which the manufacturer experienced of repeatedly adding a new zinc as soon as the former was dissolved.

(251.) The precipitating trough may be either the horizontal or vertical. The vertical trough is an oblong wooden vessel cemented in the interior; on one side the plate to be multiplied is placed, on the other a piece of copper to be dissolved. (fig. 3 b.) The horizontal trough is a shallow, square vessel, on the bottom of which the plate to be copied is placed, and half an inch above it, the copper to be dissolved. (fig. 4 b.) It is necessary to place the negative plate underneath, or else the uniform strength of the solution would not be preserved, but a mass of crystals would be deposited at the bottom of the vessel. The first apparatus is best adapted for a slow precipitation, but the last for a rapid deposition of the metal.

Which ever process be employed, the trough must be filled with a solution of sulphate of copper of a strength suitable to the power of the battery. If one battery be used, it should consist of a saturated solution of sulphate of copper, diluted with rather more than one third of dilute sulphuric acid. A solution of nitrate of copper may be employed of about one pound to the pint and a half, which will allow the deposit to take place more quickly. Nearly a saturated solution of sulphate or nitrate of copper may be used, if a series of four or five batteries be employed, or the solution be kept at a high temperature. It is advisable to place the plate in a neutral solution at first, and afterwards, when it is slightly covered, into the acidulated solution, in order that the film of air may not be removed.

(252.) Where practicable, the solution should always be kept at a boiling temperature; as by that means the deposit will take place far more rapidly, and the copper will be more elastic. The reader must not confound the property of elasticity with flexibility, although this is an error very commonly made. Flexibility is the property which bodies possess, of being easily bent; elasticity is the power which bodies have,

of returning to their former shape after they have been bent. The flexibility of any metal is a property very readily obtained by the laws pointed out; elasticity, on the other hand, is a property more difficult for the electro-metallurgist to obtain than any other.

(253.) Having filled the trough with the liquid, we take a piece of copper the same size as the plate, and connect it by a wire to the silver of the battery. We have now the battery charged, the precipitating trough filled with its solution, and the piece of copper to be dissolved placed in the precipitating trough, and connected with the silver. Having proceeded thus far, the wire, soldered on to the copper plate on which the new deposit is to take place, must be connected with the zinc of the battery, and the operator must be particularly careful that dropping the copper plate into the precipitating trough is the last operation for completing the galvanic circuit, as immediately a precipitate of pure copper commences. This does not adhere to the copper plate, because it is not in contact with it, for a thin layer of atmospheric air is interposed between the two. (fig. 3.) (fig. 4.)

(254.) Having put the apparatus in action, the operator must regulate the quantity of electricity passing, by approximating or increasing the distance between the two poles in the precipitating trough, according as he may require differences of texture in his copper; for the reduced metal may be obtained as soft as lead, harder than steel, or of any intermediate quality; the copper should neither be too crystalline nor too flexible, but should be of a texture intermediate between both extremes, and the laws regulating these have been quite sufficiently dwelt upon. The apparatus will require no material alteration for two or three days, and then the acid in the battery should be changed, and the zincs, if necessary, renewed. The piece of copper forming the positive pole should always be examined, and removed if necessary. A plate should not be allowed to remain inactive in a neutral solution for any considerable time whilst it is being made, as in that case the reduced copper is apt to be in layers.

(255.) The single cell apparatus is not at all well adapted for making copper plates, because it is impossible to regulate, with accuracy, the quantity of electricity to the strength of the solution. In fact, all the largest and most perfect plates hitherto made, have been produced by the battery apparatus.

(256.) The time necessary for the complete formation of a plate, varies according to the thickness of the copper required, the ease with which the solution suffers decomposition, the power of the battery, and the distance between the plates in the decomposition cell, or precipitating trough. The shortest time in which it could *possibly* be made, is from twenty-four to thirty-six hours, but with a single cell and dilute acid, it ordinarily takes a week, or even more; the texture of the copper however, in both cases may be made similar. The only limit which is afforded to the rapidity of the process, is the cupreous salt. As the nitrate is the most soluble salt of copper, we never can obtain a plate more rapidly than the strength of its solutiun will allow.

(257.) Having made the plate, we have now to take it off; and for this purpose, any copper embracing the edge of the original plate is to be removed; after which, the operator without any difficulty may separate the plates, for provided he has followed exactly the directions which I have before given for insuring a film of air on the plate, there will not be the slightest adhesion.

(258.) A plain copper plate is thus made, which can be used at once by the engraver, or it may be hammered and rubbed with charcoal, as copper plates ordinarily are. Duplicate copper plates have been made from another similar plate, but we can obtain a copper plate from smooth substances, which are not capable of being acted upon by the fluid; thus, smooth white wax, sealing wax, or smooth plaster of paris, will receive the deposit after they have been black leaded.

(259.) The manufacturer who makes electrotype plates in an extensive way, must endeavour to lessen the expense of the

process by every possible means. In the first place, he must recollect that the mercury used for the amalgamation of the zinc is not at all acted upon, but that when all the zinc is dissolved, it remains upon the fine particles of foreign metals which the zinc contained. He should carefully preserve this mass, as well as all the fragments which have been left. The mercury may in great part be separated from this, by enclosing the mass in wash-leather and squeezing it. The rest may then be obtained by distilling the residue. Theoretically, the operator ought to obtain again as much mercury as he originally employed; but practically, he will always suffer a certain loss.

The sulphate of zinc left in the battery, after it has been exhausted, is absolutely pure; and therefore the solution may be evaporated, and the crystals of the sulphate of zinc obtained; or the metal may be converted into a carbonate, for which there is great demand in the arts. The deposited copper in the same manner is also pure, and therefore all the clippings should be preserved for the purpose of alloying gold, as it is necessary to have a perfectly pure metal for that purpose.

Those who manufacture a great number of plates, and to whom time is not an object in their proceedings, can adopt a peculiar form of battery. The battery should be very large, and should be connected, not to one precipitating trough alone, but to a series arranged exactly as a compound battery; thus, if twenty troughs were arranged and connected with the battery, they would obtain twenty pounds of copper for one pound of zinc dissolved. The solution of sulphate of copper in each cell should be rather more dilute, and be much more acid, than when a single trough is employed, and the positive copper plate and negative plate of each cell, should be of the same size. The large battery, in this case, is not attended with more expense than a small one; for to do any given amount of work, as much zinc would be dissolved in a battery made of a silver thimble, as in one exposing a surface of negative metal, equal to the surface of

the whole of Europe! The rationale of this apparent paradox is explicable by the important law, that "in every cell the amount of chemical action is the same;" one battery will therefore, for every pound of zinc dissolved, precipitate one pound of copper in each precipitating trough, and therefore the number of precipitating troughs, arranged as a compound series, will give the number of pounds of copper thrown down, for each pound of zinc dissolved.

(260.) In this great commercial city it is useless to mention the excellence of the process, nnless, at the same time, some idea be given of the expense attending its adoption. This, with a single battery and precipitating trough, will be first the intrinsic value of the copper, say one shilling and two pence for each pound, plus an equivalent of amalgamated zinc one shilling, plus some zinc lost by local action, plus sulphuric acid, say four pence, equal to two shillings and sixpence a pound for the bare cost of the materials. To this, labour, time, house rent, and profit are to be added, which will increase, at present, the price to one sovereign per pound of copper, though doubtless the expense will be diminished as the demand increases. For plain plates persons would hardly like to give this price, unless an engraver were about to execute a very splendid subject, and then perhaps it would be fully worth his while to go to the extra expense, from the superiority of his material.

CHAPTER III.

ON COPYING ENGRAVED COPPER PLATES.

Engraved copper plates, 261. Design on the plates, 262. Various kinds of engraving, 263. Uses of engvaved plates, 264.—For the potteries, 265.—For calico printers, 266.

(261.) Engraved copper plates are not more difficult to copy than plain ones. A plate possessing the most elaborate design, the most brilliant conception, the finest execution, the

most delicate workmanship, in fact every thing calculated to render a plate valuable, is to be copied with the same readiness, the same fidelity, the same ease, as the plate without any workmanship at all; because the deposit of new metal takes place in such a way, that an exact cast is made in both instances.

(262.) The design of all engraved copper plates is either in intaglio or depressed below the surface, and the problem is to obtain a duplicate in a similar state. To effect this, a reverse of the plate must first be taken in relief. This may be done in various ways. In the first place, a relievo may be obtained in copper in the same way, precisely, as a duplicate plain plate. (249—257.) This is the most perfect process, and should always be adapted for very delicate designs.

An impression of a plate may be made on perfectly clean lead, by placing the lead on a printing press with an iron bottom, and then placing the engraved plate upon the top of it. The two are then to be run through the press, exactly in the same way as an ordinary print is taken off. In this operation, if the lead be placed underneath, a very perfect impression may be effected; but the upper plate is sure to become bent, which is a disadvantage. If the copper plate is placed underneath, that will receive no injury, but the lead will be curled in a similar manner. Now on considering these facts it occurred to me, that if a third plate above the other two were employed, there would not be any curling, and upon the experiment being tried by Mr. Bawtree, my expectations were realized, for neither lead nor copper were curled to any amount. The mode by which I directed the experiment to be performed, was to place smooth lead at the bottom, then the copper plate upon this, and lastly a third metallic plate at the top, which became curled by the process.

A perfect mould may be taken from an engraved plate in white wax, but it requires some practice to copy a large plate. The white wax must be black leaded, and then placed in the solution. Plaster of paris may also be used to take a relievo impression, and the stereotypers are very excellent hands at

using this substance; but although I have made duplicate copper plates from plaster, I am afraid that it will scarcely be thought sufficiently perfect to be used for the electrotype. The plaster must be very carefully filled by the methods I have elsewhere detailed, and after the application of the black lead it may be placed in the solution.

Having by any one of these methods taken a relievo impression, a reverse is again to be taken, in a manner similar to that pointed out for copying a plain plate. The film of air, which substances acquire by exposure to the atmosphere, must be obtained before the object is placed in the solution. (249—257.)

(263.) The back of the reduced plate will be always more or less rough, which is to be filed smooth before a print is taken from it. Sometimes, when the plate is thin, a second plate of tin or iron is soldered into the back; but the unequal expansion of the metals, when heated, is liable to be attended with inconvenience. By the use of this artificial back however, we can employ the crystalline copper, which is so intensely hard, that in all probability the plate would last much longer.

The front of the plate is liable to exhibit over its otherwise polished surface, an appearance in copper, as if the slightest breath, or film covered the surface. This has been termed, technically, the curd, and is instantly removed by the copper plate maker, by a few slight touches with his charcoal. To account for this curd will not require much thought, when we mention, that if the operator simply place his finger on a polished plate, the copper reduced upon it would have precisely similar marks; and I have seen it exhibit every line of the finger, and even the openings of the perspiratory ducts!!

(264.) Those not much acquainted with the execution of engravings, perhaps will be astonished at the various means which engravers employ to execute an engraving. They may be however divided generally into three heads. The first contains those cases where the design is made by instruments of various kinds, as gravers, dry points, &c. In the second, the device is obtained by acting partially on the plate, by acids

capable of dissolving it, or in fact by biting out the lines or figure of which the engraving is constituted. The third kind, where a plate is uniformly raised up by an instrument, in such a way that it prints all over perfectly black, in which state it is ready for the engraver. By burnishing the plate all the asperities are rubbed off, and that portion thus treated prints whiter, so that by regulating the degree of burnishing, the different effects of light and shade are produced, which constitute the engraving. This is called mezzotinto. It is far cheaper than the line engraving, and is now much in vogue. Each of these three classes of engraving Mr. Palmer has copied with the utmost fidelity, so that the application of the electrotype may be said to meet every case for which it is likely to be required.

(265.) Engraved plates were not employed till the fourteenth century, but now their uses are manifold. To hand down to posterity, and to diffuse among the multitude copies of the choicest pictures and other works of art, is one of the most prominent applications. To perpetuate the resemblance, and to distribute the portraits of the great, the good, and the beloved, is another important use. With these the public are most acquainted, but they do not constitute a tenth part of the purposes for which engraved plates are required. The great consumption now of these plates is at the potteries, for almost every common dinner service, or every piece of pottery, has its design given by a copper plate. The device is deeply cut in the copper, and then it is printed on a piece of thin paper; but the plate is printed with a composition of arsenite of cobalt, instead of the ordinary ink. The paper is then pressed upon the plate before it is glazed, in order that the ink may adhere to it; after which the paper is carefully washed off. The plate is next glazed, and is then ready for use.

The most unmeaning devices are printed on the plates, and the willow and other similar patterns certainly exhibit no great beauty of design. Yet our common pottery ware is the envy of every foreign country, for no where but in Britain

have they ever been able to make common earthenware with any degree of perfection. The electrotype promises to materially improve the patterns of our otherwise unrivalled pottery, for the expense of engraving valuable plates has been hitherto such, that on account of the small number of copies they will afterwards print, their application has been necessarily prevented. Now if a plate cost originally a thousand guineas, an infinite number of duplicates could be taken from it by the electrotype, and in this way the expense of every common dinner plate would be the same, whether the ordidary blue and white service were used, or plates and dishes were embellished with copies of our finest works of art, the most exquisite scenes of nature, the most elaborate machinations of fancy, or the most intricate specimens of execution. Before long I trust that the silly devices we have at present in use, will be changed for more elegant and highly finished drawings.

(266.) A second extensive application of copper plates, is to be found in the manufactories of the calico printers. They employ copper plates for printing their calicoes. In these instances, the copper plate is first engraved, and bent round so as to form a cylindrical roller, and then the two edges are soldered. By contrivances the die is placed by other rollers into the hollow of the engraving, when the calico to be printed passes under the roller by the force which the roller itself exerts from the revolution which is imparted to it by a steam engine. In this way twenty or thirty yards of calico can be printed in a few minutes. These copper plates might be either multiplied before they are bent, or afterwards, upon the same principles that plain electrotype copper plates are made. There would be no great difficulty to make a perfect copper roller without any solder, should that be a desideratum to the manufacturer.

CHAPTER IV.

ON THE MULTIPLICATION OF STEEL PLATES.

Process for making a copper plate from a steel one, 267. Perkins's apparatus, 268. Comparison between the two processes, 269.

(267.) Steel plates can only be copied in a peculiar manner. They must not be placed either in the sulphate, nitrate, or muriate of copper, as certain destruction would ensue. I have heard of steel plates being thus destroyed, and therefore I particularly dwell on the fact, to prevent its repetition. The crystallized acetate of copper is not decomposed by steel, though after the galvanic current has been passing for some time, free acid is left, which is apt to attack the steel. A steel plate, however, undergoes no change in an alkaline ammoniuret of copper, ammonio sulphate, or ammonio nitrate of copper. From these salts, therefore, the copper may be thrown down upon the steel, but I am afraid that no advantage can be taken of the fact, as the reduced copper is apt to scale off the plate. Under these circumstances, we must therefore have recourse to another method of making a relievo duplicate from a primary plate of steel. This may be done, in either lead, wax, plaster, or any other substance on which we can obtain a perfect cast, and from this a copper plate can be again made in the same way.

(268.) Before I bring to a conclusion a description of the method by which duplicate copper plates can be obtained from primary plates either of steel or copper, I think it necessary to mention, that metallic plates may be multiplied not only by voltaic, but also by mechanical means. This latter method has been in use for some years, and was devised by that original mechanic, Mr. Perkins, who obtained a patent for his invention. The apparatus he employed may be described in a few words; he first engraves on soft steel plates, and then hardens them. From the intaglio impression of

the device, he obtains a relievo impression on a circular roller of soft steel, by employing an immense pressure on the roller as it revolves. The circular roller which has the drawing in relievo is then hardened, when any given number of printing plates can be made from it, in a very short space of time, by placing a plain plate under the roller, and causing the roller to revolve whilst under an immense pressure.

(269.) These duplicates by Mr. Perkins' process are never such perfect copies of the original, but that engravers can tell one from the other, on account of an apparent imperfection in the plate, which requires the plate to be touched up. It is needless to add, that this immediately destroys absolute identity. The duplicate obtained by electricity is perfectly identical with the original plate, and no engraver can tell the original when both are placed before him. However, there is one circumstance which is very singular, namely, that the duplicate or second plate gives a more beautiful impression than the original. This variation does not arise from any difference of tint, for this depends more on the printer than the plate, and is technically termed the pull. In fact, a copper plate printer can print the same plate of several degrees of shade, depending upon the quantity of ink which he leaves in the work. The beauty of the duplicate over the original, perhaps, is to be attributed to the superior quality of the copper, which gives a better tone to the impression, for certain it is that every electrotype is slightly superior to the original plate.

CHAPTER V.

ON THE MULTIPLICATION OF WOOD-CUTS.

Design on wood-cuts, 270. Process, 271. Conclusion, 272.

(270.) Civilized nations ought to regard the first application of wood cuts with peculiar veneration, as they seem

to have suggested the idea of printing. At the present time, however, wood cuts demand especial notice, on account of the beauty of their execution; for they have now been brought to such perfection, that in minuteness and sharpness of drawing, I have seen specimens which fairly rival steel engravings. They do not often require to be multiplied, because it is almost impossible to wear them out; I have heard of 10,000, 20,000, 50,000, nay, even 100,000 impressions, having been taken from one wood block. Still, should we desire a duplicate of these on copper, it can be readily executed. Wood cuts are somewhat the reverse of copper plates; for in the latter, the print is obtained from the ink left in the hollows of the plate, but in the former the design is the most elevated part, and the impression is printed from the ridges.

(271.) An intaglio copper mould may be obtained from a wood cut by simply blackleading it, taking care that its back and sides are first coated with wax or grease, to prevent the wood absorbing any of the solution; the remaining part of the process is similar in all respects to that for making duplicate copper plates, and the best mode of treating wood cuts. The first copper reverse obtained, must again be copied, when a fac-simile in copper will be obtained of the device in wood. The trouble of preparing the first copper intaglio, may be avoided by taking a mould of the wood block in wax, plaster, ar any other suitable material, and then proceeding according to the general directions for copying these substances. The multiplication of wood cuts in this way, will perhaps never come much into use, for a perfect stereotype copy can very readily be obtained.

(272.) The different cases in which electro-metallurgy is serviceable for the various departments of printing have been now described, and it appears to me that the general name of electrotype ought to be restricted to these cases; for although the propriety of the term when thus employed, cannot be doubted, yet an extension of its use for dissimilar purposes, is certainly inaccurate. The electrotype, therefore, I consider

as one of the subordinate branches of the general science of electro-metallurgy; though doubtless, as the importance of the art for our manufactures is extremely great, so also its interest is increased, from its being the first department in which the electric fluid has ever been used extensively among the manufactures of the country.

CHAPTER VI.

ON MULTIPLICATION OF THE DAGUERREOTYPE.

Value of the electrotype for the Daguerreotype, 273.—Process for obtaining the duplicate, 274.

(273.) Papers and periodicals from time to time have contained accounts of the multiplication, in copper, of these splendid works. The success, however, which has attended these operations, I am afraid has not been so great as has been reported. From my own knowledge, I have but little to narrate upon the subject, and this has been confined to the observation of two plates multiplied in this manner. The image on the copper duplicate of one was moderately distinct, but it did not become visible till it had been exposed to the sun's rays. In this case, there was nothing left on the original plate, nor was any thing visible in either, till exposed to the light. On the original, however, the image never returned, but it was uninjured, and therefore it might be employed again. The second plate was a duplicate in copper, from a plate of Dovor Castle, executed by Dr. Symon, of that town, and he informed me that the image also did not appear for some time. His view on this plate is more faint than that in the first plate, which is further increased by the reflection of the copper being nearly the same at the places where the image is, as where there is no device. There is also the peculiar appearance on the plate, which is technically called the curd. Dr. Symon informs me, that the impression

will bear rubbing when it is apparent, but that the copper deposited upon a great number of plates had not the faintest trace of any view upon it. In one of these cases, the image was transferred from one plate to another, rather than multiplied, because there was no increase of images, but the image of the silver was only removed to the reduced copper, leaving the original plate quite plain and polished. In the other original plate, however, a faint image was left.

(274.) The process for the multiplication of the Daguerreotype is similar in all respects to that detailed for the multiplication of plain plates. Dr. Symon used the single cell apparatus, but I believe that the battery will be found the best adapted. The film of air, so often noticed, must not be forgotten for the Daguerreotype.

It has been a subject of regret that I have not been able to experiment on this subject, but having postponed the matter till late in the year, the feebleness of the sun precluded the possibility of obtaining plates on which to operate. It is necessary here to call the attention of my reader, that notwithstanding Monsieur Daguerre was liberally rewarded for his invention in his own country, and that France proudly vaunted of her liberality in giving his discovery to other nations, yet a patent is taken out for practising the Daguerreotype in England, which renders it illegal to apply it, without the especial license of the patentee.

BOOK THE SIXTH.

ON GALVANIC ETCHING.

(275.) All our previous operations have been conducted at the negative pole of the battery, but at the positive pole certain effects take place, which may be taken advantage of in the arts. Let us call to mind the fact, that silver and all metals with a greater affinity for oxygen, are dissolved when made the positive pole of a cell charged with a solution of the same metal. Now the relative distance which is maintained between the positive and negative poles affects the degree of solution which takes place. This property may be easily shown by attaching a wire by one of its ends to the silver of the battery, and placing the other in a solution of sulphate of copper, in the bottom of which a piece of copper connected with the zinc of the battery is immersed. After a short time, the wire will begin visibly to be dissolved, and the part nearest the negative metal will be affected. This will go on till the wire is dissolved, in such a manner that the part nearest the negative metal will diminish to the sharpest point, and the different degree of action will produce a perfect taper.

(276.) Although this property is of no value in its application, yet I have introduced it to show the facility with which

the copper in every place is dissolved exactly in proportion to the electricity passing, and this is likely to be extremely valuable for engravers in their etchings. The term etching, is given to those engravings where the lines are not cut by any instrument, but are dissolved out by an acid. In order to make an etching, a copper plate is first to be prepared by covering it with a substance which protects it from the action of the acid in which it has to be immersed. The substance used for this purpose is composed of asphalte and wax in equal proportions, combined with a fourth part of both black pitch and burgundy pitch. This mixture is placed in a piece of silk, and rubbed over the copper plate, which is kept at a moderate heat, by holding it over a lamp or chafing dish. This operation is technically called laying a ground; this at first is colourless, but it is afterwards blackened by holding it over the flame of a candle, and depressing it till a copious supply of smoke covers the surface.

The engraver, with an instrument like a needle, called an etching point, executes his drawing, and in so doing removes the ground, and exposes a clean surface of metallic copper. The plate is then placed in a dish, and dilute nitric acid poured upon it, till the copper is dissolved out from the exposed lines to a sufficient depth. The plate is not allowed to remain in the acid a sufficient length of time to bite deeply, as this would cause the engraving to be all of one degree of blackness; but after it has been in the acid a short time, those parts which are required to be of a light shade are stopped out, that is, they are covered with brunswick black, or a coat of varnish capable of resisting the action of the acid; the plate is then replaced in the dilute acid, when after a time it is again removed, and a farther portion is stopped out; and these operations are repeated as many times as there are differences of shade required in the engraving. The degree of perfection that the professed engraver obtains by practice is truly extraordinary, considering the uncertainty which must attend the

operation; for the action of nitric acid is not subject to any regular laws, and moreover is never alike over all parts of the same plate. This is owing to the copper plate itself being never pure, but always containing tin dispersed here and there throughout its texture, which resists the action of the acid, so that after a splendid plate is bitten in, some portions are left which cannot be acted upon by the nitric acid, but absolutely require the graver to bring up the fine lines.

(277.) No engraver that I have conversed with, can explain the cause of these faults in their work, but to the chemist they are perfectly intelligible; the nitric acid attacks the copper, forming a soluble nitrate of that metal which is dissolved in the fluid; but the action of nitric acid on tin, is altogether different, for it converts the metal into a peroxide, which being insoluble, protects the copper from the acid. The engravers have always noticed this white powder, (the peroxide of tin) so fatal to the success of their operations.

(278.) Etching by galvanism is a far more certain operation than the foregoing, because it can be reduced to known principles. In this case, the plate to be bitten in, has the device first drawn upon the same ground that is used in the ordinary process; the back and edges of the plate are then coated with wax, when it is to be connected, by means of a wire, with the silver plate of one or two of my batteries. A piece of copper, of the same size as the plate, should then be connected to the zinc, when both the copper plate and the piece of zinc are to be placed in a solution of sulphate of copper. Immediately copper will be reduced from the solution on the negative plate, and copper from the etching plate will be dissolved to keep up the strength of the solution.

Whatever is favorable to the increase of electricity, causes the copper to be more quickly acted upon, and whatever diminishes the galvanic current, retards the solution of the metal; so that the nearer the etching plate, forming the positive pole, and the piece of copper forming the negative, are approximated, the more rapid will be the action. In the

same way, the intensity of the battery also affects the rate at which the plate is bitten in. The negative plate of copper, however, should not exceed in size the copper plate on which the etching is executed, or else there is a risk of some of the lines being more deeply bitten in; and in like manner, if any considerable part of the plate has a great deficiency of lines compared with other parts, that part must be stopped out rather before the other, to ensure a uniformity of depth, or else the negative copper opposite the part must be so bent, that it is at a greater distance.

(279.) The advantages of galvanism for etching, are, the absence of poisonous nitrous fumes, which are evolved in the ordinary process; the greater uniformity of action which takes place than when acids are used, and that the rapidity of biting may be regulated to the greatest nicety. The lines may be made of any depth, and are sharper and cleaner than when acid is used; and lastly, no bubbles are evolved, which the engraver well knows are apt to tear up the ground, or to cause unequal action.

(280.) The exact quantity of copper dissolved from the plate, can be ascertained by weighing the metal reduced on the sheet of copper which forms the negative pole, or by measuring the quantity of hydrogen evolved from the silver plate of one of the platanized silver batteries, for thirty-two grains of copper will be dissolved for every forty-eight cubic inches of gas evolved.

Etching by galvanism can be executed with any desired degree of rapidity, according to the series of batteries to which the plate is connected; but I believe that the practical man will find that the action should neither be too slow nor too quick, and perhaps two or three batteries, arranged as a series, will be found best adapted, though a single cell would suffice.

(281.) Galvanism would be valuable to the engraver for executing gradations of shade, such as, for instance, the effect of a strong light illuminating a whole room. The most simple manner in which this can be shown, is to take a copper plate

and draw a number of lines on the ground with a ruling machine. The plate, after having its back and edges coated with any non-conducting substance, should be then connected with the silver of the battery, and a piece of copper of the same size joined to the zinc. These two should be then so arranged in the solution of sulphate of copper, that at one end they nearly touch, while at the other they are widely apart. By this position, the greatest quantity of electricity would pass at that part of the plate where it is nearly in contact with the negative pole, whilst the least would pass at the opposite extremity. The action on the etched plate being exactly in proportion to the quantity of electricity passing, is unequal over the whole length of the plate, being greater where the metals are nearest, and gradually diminishing to the other end. This is the most perfect mode by which it is possible to obtain a gradual gradation of shade. Many variations in the arrangements might be made by using, as a negative plate, a wire or a rod of copper, placed over the centre of a prepared plate, for then a perfect gradation would be obtained, extending in all directious from the dark centre. In the same way, two or more radiating shades may be obtained, by using two or more negative wires. An insensible gradation might be made from the darkest shade at the external edge of the plate, to the lightest point at its centre, by cutting out a hole in the negative piece of copper, opposite to the part where the transition into light is required.

(282.) The professed engraver who once practically masters the galvanic method of etching by the theoretical principles which I have here detailed, is sure to obtain great results. He could execute, with ease, the most extraordinary transition of light into darkness with fidelity, and with the utmost certainty. However, I trust that the value of electric etching will not be confined to the artist; for by removing the disagreeable consequences attending the use of nitric acid in the present mode of etching, more persons may be induced to enter into it, and by this means, numbers studying the sciences, will

be enabled to execute an etching of those objects which are curious and rare, to send to their brethren who are studying the same subject. Those travelling in foreign countries, or in picturesque situations, might transmit to their distant friends an idea of the sublimity and grandeur of the scenery which they are enjoying, or of the appearance of the towns and villages through which they are passing. In fact there is not a person who might not be benefitted by receiving etchings from others, and who might not, in return, circulate engravings of those objects which he may see. Pictorial representations are avowedly better than any verbal descriptions, so that there is ample scope for any one to exercise his talents usefully, and certainly many cannot be aware that etchings are no more difficult to execute than common pencil drawings. The process is as suitable for ladies to practise in their drawing rooms, as are any of their usual amusements; the operation being attended with as little trouble. It is necessary at first to have the plate prepared, or have a ground laid, which might be done by a workman, at the conclusion of the drawing it has to be bitten in. The objection to this hitherto, has been the disagreeable properties of the acid, as it is likely to spoil their clothes or injure the furniture; but now that these objections are removed, I trust that numbers will enter into this amusing and useful branch of art.

CONCLUSION.

I have now detailed briefly, but I trust usefully, the properties of bodies which are called galvanic, aud the effects which galvanic batteries produce, as far as relates to the interesting subject of electro-metallurgy. Our science, even in itself, is essentially dependant upon galvanism, and the precipitating apparatus employed is nothing but a battery cell. With regard to the laws regulating the metallic deposit, and the metals capable of being deposited by the voltaic current; these are derived from my own observations. The importance of these laws to the operator, will be to enable him to proceed with certainty. The reason which has induced me to devote so much labour and thought to these laws, has arisen from a conviction that the electrotype must have dropped, unless the operator could proceed upon certain fixed principles. The extension of the few isolated facts formerly known, and their enlargement into a general science will, I trust, be found useful to those engaged in prosecuting these operations.

The influence which this new science will have on the arts, manufactures, and commerce of our great country, it is scarcely possible to foresee. The extended use of galvanism for manufactures requires the utmost encouragement, and the improvements must not be shackled by patents, if we desire the scheme to succeed; for the ingenuity and the talent of the whole country is required to place it upon a firm footing.

The multiplication of copper plates will cause a far greater demand for them than has ever existed heretofore, and the engraver need be under no apprehension, for not only will his

talents be more required, but he will be called upon to execute more splendid specimens of art; for as these can be multiplied ad infinitum, a large circulation will render it worth while for any publisher to pay a very high price for an original, which he conceives will meet with great public approbation. The publisher, in the same way, could lessen the price of engravings from our finest works of art, so as to bring them within the means of every person; and there is no doubt that he who first engages in a business upon the above liberal and well-known principles, will realize for himself a large fortune, and contribute greatly to the benefit of society.

For our potteries, the multiplication of plates assumes a higher importance, even than the last described valuable applications; for it enables the manufacturer to improve the designs upon our otherwise perfect earthenware, and then all countries will indeed be jealous of what they are already otherwise inclined to look upon with envy.

Our calico printers will also now be enabled to use far more costly plates than they have hitherto employed.

There are many other applications of this science, besides those which I have already detailed; such as the capability of adding copper to copper, and other similar purposes, which cannot be effected by any other process. Another important application of galvanism, is the means which it is likely to afford of separating one metal from another, or from its ore. This subject is so vast, that had I entered upon it, another twelve-month would have elapsed before this work could have been printed. It appeared to me better not to incur this delay, especially as I hoped that the public would be benefitted by receiving at once the laws and principles which I had discovered.

A great variety of the applications of electro-metallurgy may appear to many to be trifling, as they contribute only to embellish the drawing room and gratify the eye; but let them remember, that if private persons engage in the manufacture

of these little trifles, it will lead to a knowledge, and a practical knowledge too, of the effects of one of the most important and universal agents operating in nature. If manufacturers engage in them, it will lead to a more general use of the galvanic battery, which doubtless will eventually hold an important place in our manufactures.

It is true that electro-metallurgy offers many opportunities for fraudulent proceedings, as by it the forger can copy, with ease and unfailing accuracy, any embossed surfaces or stamps, and therefore no embossed work whatever should be used, where there is likely to be any inducement for copying. By it, seals may be forged, and an impression may be taken off a copper plate, if it only remain in the possession of the party for a few seconds; besides, our new science gives the false coiner many opportunities to further his fraudulent practices. These things are particularly pointed out, to put people on their guard against the designs of bad men.

Science however must not stop because some of its applications are liable to be turned to bad account by the evil designed; and we must recollect that those things which can be forged by the electro-metallurgist, could also be forged by other processes before known. It was a favorite maxim of our great countryman, Wollaston, that "whatever man can execute, man can also copy," and therefore the very idea of any device being inimitable is absurd.

Of the value of electro-metallurgy to the arts and manufactures, even in the present state of the science, there can be no doubt. It is not now a question of probability, whether this science is practically applicable or not, for we have detailed fully what has been done by its agency—we have given full descriptions of all the various processes for obtaining with certainty many results—and finally, we have arranged all the facts into a tangible and systematic form, and by laying down laws by which all its operations are governed, reduced the whole into a vast comprehensive science.

It may be indeed a matter of conjecture, to what extent

this science may be ultimately carried out, or to what other purposes it may be applied in years to come; but were it never to be applied otherwise than it has already been, were it to stop for ever at the point to which we have now brought it, no one can deny that it is a most valuable acquisition; in short, we may safely assert, that no other single discovery ever presented capabilities, at once so many, so various, so interesting, or so valuable.

This science depends for its very existence on electricity, and among the indirect benefits, which it may surely be hoped will arise from it, we may mention the study of electricity generally, of which gigantic power so little is known, and which, from the little we know of it, plays so important a part throughout nature; for though all of us recognize its operation in the thunder storm, and view with terror and amazement the devastating violence with which, at such times, it makes known its power, yet, at present, how little do we know of the effects which it may at all times be producing around us, by its silent and continued operation.

The science of electricity is perhaps one of the most sublime examples of the might of human intellect, for by its agency, man has made obedient to his will, a power capable of producing such vast and terrible effects. "Nil mortalibus arduum est," says Horace, when speaking of Promethus, who was fabled to have stolen fire from heaven, and modern science has proved again and again the truth of the assertion, though little could he have thought when writing the passage, how nearly the fable of Prometheus would in after ages become verified.

To the young chemist, we would particularly recommend the study of this science, and should he be tempted to turn his attention to it in a systematic manner, he will be amply rewarded for his trouble. The results of his experiments are lasting, and will be contemplated by him in after years with pleasure; whereas, chemistry, being too often used as a source of amusement, brings forth very different results. The ex-

periments tend to nothing, and end in nothing, beyond the present gratification; they illustrate facts which have been illustrated exactly in the same way a thousand times before, and are usually selected to be gone over and over again, purely because they possess some incidental character, which is calculated greatly to astonish the uninitiated spectator, and to enhance the scientific acquirements of the operator. By such a course of proceeding, (for, undoubtedly, such it very commonly is) nothing is done, either directly by the operation, or by increasing the knowledge of the operator, and there remains nothing to show for the labour and money expended, except perhaps, the trouble of clearing away the remains, or what is not so easily accomplished, the rectifying of the mischief done to furniture generally. We have no hesitation in saying, that electro-metallurgy will afford as much or more gratification, as an intellectual pursuit, and infinitely greater satisfaction in its results.

In conclusion, we cannot too often impress upon our readers the advantage of making themselves thoroughly conversant with the principles upon which the operations of electro-metallurgy depend, and the laws by which these operations are in all cases governed. By hurrying at once into the performance of the various processes, without thus qualifying themselves, what can be expected but failure, and its consequences, disappointment and mortification. Proceeding in ignorance of the rationale of the process, untoward circumstances are for ever marring the designs of the operator; experiment follows experiment, and failure follows failure—materials are expended in vain, and after the loss of much time, the student (if such he can be called) is tired of a science which has yielded him so little satisfaction, and throws it aside in disgust, perhaps attributing its uncertainty to that which is the pure and absolute result of his own idleness and consequent ignorance. But if he proceed in an orderly and philosophic manner, making himself first acquainted with the nature and modus operandi of the materials with which he is

about to work, he cannot by any possibility, fail in his results. With such preparation, no casualty can occur, which cannot be readily referred to its true source, and consequently as readily remedied. Those who are comparatively unacquainted with electricity and galvanic apparatus, may meet with some little trouble in entering upon this science; but commencing upon a right method, their first trouble will be their last; and let them always bear in mind, that without trouble, no great good was ever accomplished.

Doubtless the galvanic fluid will, before long, be as important to the manufacturer as the heat of a furnace. At present a person may enter a room by a door having finger plates of the most costly device, made by the agency of the electric fluid. The walls of the room may be covered with engravings, printed from plates originally etched by galvanism, and multiplied by the same fluid. The chimney piece may be covered with ornaments made in a similar manner. At dinner the plates may have devices given by electrotype engravings, and his salt spoons gilt by the galvanic fluid. All these, and many other applications we may have at present, but we must still look forward to the most important properties of the electric current derived from the galvanic battery; for although great and glorious are the triumphs of science detailed in this work, yet the prospect of obtaining a power which shall supersede steam, exceeds in value all these applications. For to cross the seas, to traverse the roads, and to work machinery by galvanism, or rather electro-magnetism, will certainly, when executed, be the most noble acheivement ever obtained by man.

FINIS.

ANALYTICAL INDEX.

ERRATA:

page 21, line 9, " + a local action," read + a "little local action."

„ 35, under anions, for "Fulorine" read "Fluorine."

„ .... for "Sulphoganogen," read "Sulphocyanogen."

„ 38, last line, for "(r)" read "(r')"

„ „ Ohm formula for $\frac{n\,E}{r \times n} r'$ read $\frac{n\,E}{r + n\,r'}$

„ 66, line 5 from top, omit Manganese.

„ 134, lines 7, and 8 }
„ 135, lines 9, and 14 } for "Daguerrotype" read "Daguerreotype."

„ 134, line 7 }
„ 135, line 15 } from the bottom, "Symon" read "Simon."

B. 8
E - 4
Pl — 5
Portman — 1